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REPORT

OF

THE SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR

THE YEAR ENDING ~~JUNE~~ 30, 1884.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1884.

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Act. 13

Astronom. Observatory.

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UNITED STATES NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
Washington, October 29, 1884.

SIR: In accordance with the Bureau's instructions, I have the honor to submit the report of the operation of this Observatory for the past year. I relieved Rear-Admiral Shufeldt as Superintendent on the 21st of February last. After having familiarized myself to some extent with the workings of the establishment, I became satisfied that its interests would be advanced by the organization of a Board consisting of the Superintendent, the senior professor of mathematics, and the senior line officer, whose duty it should be to meet from time to time and deliberate upon the conduct of the Observatory, and whose conclusions should form a basis of work to be done for each coming year. In conformity with these views, I issued the following general order:

GENERAL ORDER NO. 1.

The scope and character of the work to be done at the Naval Observatory shall be decided upon the recommendation of a Board to consist of the Superintendent, the senior professor, and the senior line officer.

Each officer in charge of a separate branch of work shall submit to the Superintendent annually—and more frequently if any changes be desired—a statement of the condition of the work under his charge and the work which he proposes for the coming year. These statements will be submitted to the Board by the Superintendent for their opinion and criticism, and upon the conclusions thus reached the work shall be based.

The Board shall be convened for consultation as often as the Superintendent may desire, or at the request of any member. The clerk of the Observatory will act as secretary of the Board.

The work will for the present be considered as divided in the following manner:

1. Great equatorial.
2. Transit circle.
3. Transit instrument.
4. Nine-inch equatorial.
5. Prime vertical.
6. Mural circle.
7. Time (including chronometers).
8. The library.

Each officer in charge of one of the above-named divisions will submit to the Superintendent before July 1 a detailed statement of the work proposed for the next six months, and hereafter a similar annual statement will be made on each 1st of January.

S. R. FRANKLIN,
Commodore, Superintendent.

NAVAL OBSERVATORY, *June* 18, 1884.

After the programme of work for the year commencing January 1, 1885, shall have been completed, I propose to have it printed and distributed amongst our correspondents, in order that other observatories, and those who are interested in the work of this one, may be thoroughly informed of what is done here, and also to prevent the unnecessary duplication of work which might be avoided by such information.

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In order to systematize still further the working of the Observatory, I directed that reports should be handed to me every Monday morning by each officer in charge of a division, showing not only what had been done but how each person had been employed during the preceding week.

An effort has been made to establish at the Observatory a system by which all sextants and octants for issue to the Navy shall be examined and corrected, as far as practicable, and their errors, as well as those of instruments that are used for meteorological observations, be furnished to the navigators of vessels from this place, so that there would be a continuous record of every such instrument supplied by the Bureau of Navigation. I recommend that all such instruments as are found to be worthless be broken up, in order that they may be rendered incapable of doing harm to any one. As this work was discontinued when the officer in charge of it was detached, I respectfully recommend that some capable officer be ordered to the Observatory, to be assigned to this duty, who could, in addition thereto, be very usefully employed in photographing the sun each day at meridian, by which a record of the sun spots could be secured, and which, taken in connection with kindred observations at other observatories, would supply a mass of information upon this interesting and instructive subject which could not be otherwise than useful to all engaged in it.

I cannot too earnestly urge upon the Bureau the necessity of commencing the buildings for the new Observatory. The ground having been purchased and the plans made and approved, there seems to be no good reason why the construction should not begin. The present site is notoriously unhealthy, and the buildings are dilapidated and much in want of repair; and it would not be in the interest of economy to make any extensive repairs while the erection of new buildings is in contemplation. The delay is very prejudicial to this establishment in particular and to the cause of science in general. I respectfully request that if all the money cannot be appropriated for the purpose aforesaid at the coming session of Congress, a portion of it, at least, may be asked for, in order that this work, now so long delayed, may be begun.

I beg leave to reiterate the suggestion of my predecessor that there be appointed annually a Board of Visitors, to consist of a small number of scientific men, whose duty it should be to examine into the conduct of the Observatory, and make such suggestions as might add to its general usefulness. I think that by this means it would become better known and its work more highly appreciated.

THE 26-INCH EQUATORIAL.

This instrument has been in charge of Prof. A. Hall. Prof. S. J. Brown was assistant from October, 1883, to June, 1884. Lieut. W. H. Allen and Ensign J. A. Hoogewerff have rendered valuable assistance as computers. The instrument, the micrometer, and the driving-clock are in good order, and have been in constant use. For several years past the dome has been moved with difficulty. To obviate this a gas-engine of 4-horse power has recently been successfully connected with the turning machinery.

The work for the past year with this telescope consists of observations of the satellites of Neptune, Uranus, Saturn, and Mars, and of the observations of double stars. A few observations have been made for stellar parallax.

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In the case of Uranus the observations were confined mostly to the two outer satellites, and it is proposed now to discontinue them, since the favorable time for determining the position of the orbit planes of these satellites has passed. In the autumn of 1883 Professor Brown made a drawing of Saturn and its rings.

As this instrument, since it was mounted in 1873, has been largely devoted to observing the faint satellites of the planets, a great number of such observations has been accumulated.

The laborious work of discussing the observations, correcting the orbits of the satellites, and determining the masses of the planets, was begun in August, 1883; and, owing chiefly to the able assistance of Lieutenant Allen and Ensign Hoogewerff, good progress has been made. Professor Brown also assisted in this work.

The observations of the satellites of Saturn have nearly all been reduced and discussed, and equations of condition have been formed and solved by the method of least squares. The final discussion of the results and the adjustment of the weights remain to be done. This preliminary work is also nearly completed for the outer satellite of Uranus for the years 1881, 1882, 1883, and 1884. It is proposed that this work of discussion shall be steadily continued until all the observations made with this instrument have been completely reduced and the final results obtained.

THE TRANSIT CIRCLE.

This instrument, in charge of Prof. J. R. Eastman, was employed on the same class of work as in 1882–'83. The assistants have been Assistant Astronomers A. N. Skinner, H. M. Paul, and W. C. Winlock, with Mr. W. M. Brown, jr., as computer. During the year ending October 17, 1884, the whole number of observations with the transit circle was 5,420. Of these, 98 were of the sun, 84 of the moon, 151 of the major planets, 45 of the minor planets, and 11 of comets.

The meteorological observations have been continued, as in former years, by the watchmen.

THE 9.6-INCH EQUATORIAL.

This instrument, in charge of Commander W. T. Sampson, assisted by Prof. Edgar Frisby, has been employed principally in observing comets and the minor planets. There were made 134 observations of comets and 406 of minor planets. All the observations have been reduced up to date, and most of them are ready for the printer. All occultations of stars by the moon have also been observed.

THE PRIME VERTICAL INSTRUMENT.

Observations with this instrument, which has remained in charge of Lieut. C. G. Bowman, with Ensign Hiero Taylor as assistant, were maintained until May, 1884, when some 1,020 observations had been taken. They were then discontinued, except that 13 observations of *a.* Lyræ were made in June and July, at the time of maximum parallax. During May and June both observers were employed in deducing clock corrections from the observations of the meridian transit, with whose sidereal clock the Howard clock, used in connection with the prime vertical, had been constantly compared. They also made with the level-trier

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various observations to determine the value of a division of the level, and collected from all available catalogues data to deduce the mean places and proper motions of all stars used. It is proposed, however, to accept those already discussed by either Auwers or Boss, which will include some twenty of the stars observed, and to carry on the reductions, at first, of certain of the latter stars which have been most frequently observed.

Lieutenant Bowman having been transferred to the charge of the meridian transit instrument, the computations are being completed by Ensign Taylor.

THE MERIDIAN TRANSIT INSTRUMENT.

The meridian transit remained in charge of Lieut. U. R. Harris, who was assisted by Lieut. E. C. Pendleton until July last, when the former was detached, and the latter relieved Lieut. E. K. Moore of the charge of the chronometers and time service. Since that time Lieutenant Bowman has been in charge of the instrument, assisted by Lieut. John Garvin. The instrument has been used primarily to determine clock corrections in connection with the daily time service. In addition, special time signals have been sent out at the request of the Coast Survey, and observations for the right ascensions of the sun, moon, and major planets have been made. These latter have been reduced to the beginning of the calendar year.

The transit instrument is in good order, and the standard mean-time clock has performed very well. The sidereal clock has done very indifferently, but as chronographic comparisons are invariably made whenever observations are taken, no serious inconvenience has been caused.

THE MURAL CIRCLE.

This instrument is in charge of Prof. S. J. Brown. Mr. W. F. Gardner, the instrument-maker of the Observatory, during the summer put it in thorough condition, and Professor Brown is at present engaged in general instrumental adjustments, preparatory to making observations for declination upon certain stars, some 2,700 in number, a list of which has been prepared by him.

CHRONOMETERS AND TIME SERVICE.

This division is in charge of Lieut. E. C. Pendleton. There are at present in the chronometer-room 235 chronometers, of which 18 are ready for issue, 31 are on trial, 59 require repairs, and 127 are condemned to be used only as "hacks." Thirty-nine have been received from naval vessels and other sources, 6 were purchased after competitive trial, and 1 was received from William Bond & Son, in exchange for an old one of their make. Four pocket chronometers, 1 pocket half-chronometer, and 1 watch were also purchased after competitive trial. Sixty chronometers were issued to naval vessels and stations, 50 were sent to be cleaned and repaired, 55 were returned cleaned and repaired, and there are now 15 undergoing repair at the establishments of Messrs. Negus and Messrs. Bliss, in New York, and Messrs. Bond, in Boston.

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Upon the adoption of what is known as "standard time," the following circular was issued:

DESCRIPTION OF TIME SIGNALS.

(*Seventy-fifth meridian, mean time.*)

[To be sent out by the United States Naval Observatory on and after November 18, 1883.]

The signals to be sent out by the Observatory are wholly automatic, and consist of a series of short *makes*, produced in an open telegraphic circuit by the beats of a mean-time clock, the pendulum closing the circuit at each beat.

The signals begin at 11 hours 56 minutes 45 seconds and cease at 12 hours, seventy-fifth meridian mean time. During that interval there is a *make* at the beginning of every second, except that in each minute the makes corresponding to the twenty-ninth second, and to the fifty-fifth, fifty-sixth, fifty-seventh, fifty-eighth, and fifty-ninth seconds, are omitted. Thus, the first make after the pause of five seconds always marks the beginning of a minute, and the first make after the pause of one second marks thirty seconds. In order to distinguish the last minute and give time to manipulate switches to time-balls, control-clocks, &c., the makes cease after 11 hours 59 minutes, 50 seconds and until 12 hours, when there is a single make, and the signals cease.

When these signals are received at points where the time of the ninetieth meridian is used, they will give the time from 10 hours 56 minutes 45 seconds to 11 hours, or just one hour earlier than when representing seventy-fifth meridian time; otherwise the signals will be read in the manner described above.

Seventy-fifth meridian time is 8 minutes 12.09 seconds earlier than Washington time.

UNITED STATES NAVAL OBSERVATORY,
November 10, 1883.

The transmitting clock of the Observatory was set to the seventy-fifth meridian time, and the time-signals given to the telegraph companies since that date have been in conformity with the above circular.

Owing to the increased demand for the time-signals, the Baltimore and Ohio Telegraph Company looped two of its main circuits into the Observatory, and the Signal Service looped one. The facilities of the Observatory for transmitting time-signals were very much extended, the apparatus being nearly all reconstructed and rearranged, and the signals are now transmitted from the Observatory over eleven wires. The District of Columbia authorities did not adopt standard time until March 1, 1884, and up to that date the Observatory ball was dropped at noon of Washington mean time, and the fire-alarm bells of the city were struck at 7 a. m., 12 m., and 6 p. m. of the same time. Since that date the ball has been dropped at noon of the seventy-fifth meridian, and the fire-bells struck at the same hours of seventy-fifth meridian time.

In March last the honorable Secretary of the Navy, at the request of the Superintendent, submitted to the heads of the several Departments the proposition to place in the more important offices of the Government, including the Executive Mansion and the Capitol, a clock that should be regulated and controlled every day from the Observatory, which establishment should be responsible for the determination and transmission of correct time.

This plan having been generally approved, and the Departments having agreed to bear each their proportion of the expense of an insulated electric circuit to connect the Observatory with the different buildings, connection was made with the following offices, the Superintendent of Public Buildings and Grounds extending every facility in his power: Office of Commissioner of Public Buildings, War Department, Navy

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Department, Executive Mansion, National Museum, Smithsonian Institution, Agricultural Department, Bureau of Engraving and Printing, Capitol (Senate wing), Government Printing Office, Department of the Interior, Post-Office Department, City Post-Office, Pension Office (Twelfth street northwest) Pension Office (Thirteenth street northwest), Office of Geological Survey, Quartermaster-General's Office, Treasury Department, Department of Justice, Surgeon General's Office.

In each of these offices is a clock which is corrected daily at noon of standard time by means of an automatic attachment (the invention of Mr. W. F. Gardner, the instrument-maker of the Observatory), actuated by the electric current which makes the signal that drops the time-balls at the Observatory and on the Western Union Telegraph Company's building in New York.

THE LIBRARY.

The library is in charge of Lieut. John C. Wilson. The annual volumes for 1879 and 1880, and Appendix I, 1880, have been received and distributed. Our list of exchanges contains 433 foreign and 464 domestic addresses of scientific institutions and individuals engaged in scientific researches.

The library contains about 12,800 volumes, besides a large number of pamphlets, the accessions during the year being as follows:

By purchase	462
By exchange	450
By gift	107
Public documents	36
Total	1,055
Volumes	725
Pamphlets	330

A manuscript catalogue of the library has been completed to May 1, 1884, and is now ready for printing.

PRINTING AND BINDING.

Owing to the limited amount of the printing fund of the Department, great difficulty is experienced in obtaining the publications of the Observatory from the Public Printer with any degree of promptness. The volume for 1880, which it was expected would be ready by the 1st of January, 1884, was not received until October; the volume for 1881 has been ready for several months, but for want of funds has not yet been touched by the printer. For the same reason publications of a professional character which are in frequent use and require more substantial binding cannot be sent to the Government bindery. In view of these facts, and of the necessity which exists for promptness in these matters, I would suggest that Congress be urged to appropriate $5,000 annually for the printing and binding for the Observatory until the work in arrears be brought up. When that shall have been done a smaller sum will enable us to carry on the work of each year.

TRANSIT OF VENUS OF DECEMBER 6, 1882.

The work of reducing the various observations of this transit has been carried on during the year, under the immediate supervision of Prof. William Harkness, assisted by Messrs. R. S. Woodward, A. S.

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Flint, Emil Wiessner, and A. Hall, jr. The details of the work will be found in the appended report of Professor Harkness.

MISCELLANEOUS.

During the year 1,484 persons visited the Observatory by day, and 1,344 permits were issued for night visitors, for whose accommodation the small equatorial is set apart.

A record has been kept by the various observers and the watchmen of the condition of the sky as regards seeing. From this it appears that but 126 nights were clear enough for observing, and of these but 38 are recorded as good, the remaining 88 being poor or indifferent.

I respectfully urge that the estimate made for three additional computers and for the increase in the salaries of the assistant astronomers and the instrument-maker receive the favorable consideration of the Bureau. Inasmuch as the average term of service of the assistant astronomers is but three years, owing to the fact that more lucrative positions are offered to them, it would seem to be in the interest of economy that these gentlemen should be retained in the service of the Observatory by paying them such salaries as can be obtained by them from other parties, rather than to permit their trained services to be lost. The pay now received by these gentlemen is not an adequate remuneration for the services they render. The instrument-maker has a responsible position, and his familiarity with the requirements of the place, together with his attainments and long service, merit the increase which is submitted.

Very respectfully,

S. R. FRANKLIN,
Commodore, Superintendent.

Commodore J. G. WALKER, U. S. N.,
Chief of Bureau of Navigation,
Navy Department.

[Estimate.]

NEW NAVAL OBSERVATORY.

For the purpose of erecting a new Naval Observatory and necessary buildings upon the site purchased under the act of Congress approved February 4, 1880 (21 Stat., page 64), $586,138.

Respectfully submitted.

S. R. FRANKLIN,
Commodore, Superintendent of Naval Observatory.

APPENDIX.

[Report of Prof. William Harkness, U. S. N.]

UNITED STATES NAVAL OBSERVATORY,
Washington, October 27, 1884.

SIR: I have the honor to submit the following report of the work done during the past year, under my supervision, for the Transit of Venus Commission.

The assistants engaged upon the work at the beginning of the year were Messrs. R. S. Woodward, A. S. Flint, Emil Wiessner, and A. Hall,

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jr. Mr. Woodward resigned his position on the 3d of July, and Mr. Wiessner died on the 4th of August after a short illness. Both these gentlemen were excellent assistants, industrious, and thoroughly familiar with their duties, and their loss has not only been a matter of regret to the commission, but has also materially retarded the progress of the work. Messrs. Flint and Hall are still in the employ of the commission.

The measurements of the negatives of the transit obtained at the various stations were completed about the middle of August, the number of photographic plates affording satisfactory results being as follows:

	No. plates.
At Washington, D. C	50
At Cedar Keys, Fla	165
At San Antonio, Tex	121
At Cerro Roblero, N. Mex	216
At Princeton, N. J	162
At Lick Observatory, Cal	130
At New Haven, Conn	88
Total for northern hemisphere	932
At Wellington, South Africa	180
At Santa Cruz, Patagonia	211
At Santiago de Chile	197
At Auckland, New Zealand	51
Total for southern hemisphere	639

As was fully explained in last year's report, the stations at the Princeton and Lick Observatories were erected and equipped by those institutions; but as the apparatus employed was as nearly as possible identical with that of the Government parties, the negatives obtained are strictly comparable with those made at the Government stations. With the negatives made at New Haven it is quite otherwise. They owe their existence to the private efforts of Mr. R. W. Willson, and unfortunately the only apparatus he found available was of an entirely different kind from that used by the Government parties. He succeeded in obtaining 114 negatives of the transit, the image of the sun being $1\frac{1}{8}$ inches in diameter, which he very kindly offered to the Transit of Venus Commission for measurement and discussion. As these negatives seem likely to yield valuable results, the commission gladly accepted them. To sum up, then, from the Government stations 1,191 negatives have been measured; from the Princeton and Lick Observatories 292 negatives have been measured; and from New Haven 88 negatives have been measured; thus giving a grand total of 1,483 negatives, made in accordance with the methods of the commission, and 88 made by Mr. Willson's apparatus. Very considerable progress has been made in the computations necessary for the reduction of the measurements of these negatives.

In order to determine accurately the length of a second of arc upon the photographs, it is necessary to know exactly the focal lengths of the photographic objectives, and the radii of curvature of the heliostat mirrors.

The investigation of these data was begun last fall, and for the purpose of detecting and avoiding constant errors, it was decided that every determination should rest upon at least two, and whenever possible upon three, independent methods. The mirrors were taken up first. The eight belonging to the Transit of Venus Commission are as nearly as possible similar to each other, both in thickness and in mounting, but the two belonging respectively to the Princeton and Lick Observa-

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tories differ somewhat from the commission mirrors and from each other. By a process entirely similar to that employed in the production of a flat surface by grinding three approximately plane surfaces upon each other, three 6-foot telescopes of 5 inches aperture were adjusted upon each other until they were all brought accurately to sidereal focus. The draw-tubes of two of these telescopes were provided with scales and verniers, by which changes in the distance of the cross-wires in the eye-piece from the objective could be read to the one-thousandth of an inch. These two telescopes being laid horizontally, and at right angles to each other, the mirror to be examined was so placed as to reflect the rays issuing from the objective of the first telescope into that of the second. If the mirror were not optically flat, it destroyed the parallelism of the rays between the two objectives, and produced a corresponding change in the position of the focal plane of the second telescope, which was measured by means of its scale and vernier. Then from the amount of this change, and the known focal distance of the telescope for parallel rays, the curvature of the mirror was computed. This process, which may be designated as the reflection method, was applied to all the mirrors. As a check upon the results obtained from it, the surfaces of all the mirrors were compared with each other, by means of a spherometer, and thus the curvature of each mirror relatively to the mean of the curvatures of all the mirrors, was found. To obtain the absolute curvature of each mirror, the mean of the curvatures found by the reflection method was made use of. The spherometer method is therefore not quite independent of the reflection method, but it is very nearly so, and the results obtained by the two methods agreed closely.

While investigating the principal focal distance of the telescope employed in the reflection method, I found that, in practice, Gauss's method of determining the quantity, by measuring four times the focal distance and subtracting the interval between the principal points, requires the addition of a correction for spherical aberration to make it rigorously exact. As a check upon the results thus obtained, the principal focal distance of the telescope in question was determined by measuring the distance from its principal focal plane (found by the three-telescope method explained above) to the back surface of the objective, and adding to it the distance from the back surface of the objective to its second principal point; and as a still further check, the principal focal distance was also found by measuring with the transit circle the angles subtended at the second principal point of the objective, by the known intervals between certain lines ruled upon a piece of glass situated in the principal focal plane. These three absolutely independent methods gave results which were almost identical.

The investigation of the photographic objectives embraced the measurement of the curvatures of all the surfaces of every objective; the measurement of the thicknesses of both the flint and crown lenses, and of the interval between them; and the measurement of the principal focal distances of the complete objectives, and also of their crown lenses, both for visual and for photographic rays. These measurements of focal distance were made by the Gaussian method, with the aid of a spectroscope, the equivalent wave-length of white light being known, and the photographic rays being determined from photographs of the solar spectrum made for another purpose some years ago. In order to get accurate measurements of the curvatures of the objectives, I found it necessary to make some additions to my spherometers, which are believed to be novel, and to develop a more exact theory of these instruments than any heretofore published. This being done, the results

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obtained from three different spherometers, varying in size from 2½ to 5 inches in diameter, agreed very closely.

The important question whether or not the heliostat mirrors undergo any change of curvature when exposed to the sun's rays, yet remains to be considered. This problem has been attacked in two different ways. The first method consists in mounting the mirrors in a heliostat, one after the other, just as they were during the transit, and then, by means of a spherometer, comparing the mirror exposed to the sun with another kept in the shade. The second method consists in reflecting the sun's rays from a heliostat mirror through the photographic objective into the photographic house, and comparing the position of the sun's image thus formed with the position which it should occupy from the known focal length of the objective determined by the Gaussian method. Both these methods concur in indicating that the mirrors become very slightly concave when exposed to the sun's rays, but the investigation is still in progress, and it would be premature to give numerical results at this time.

With respect to the ordinary astronomical observations for time and latitude obtained by the various parties, it should be stated that those made at San Antonio, Cerro Roblero, and Auckland are completely reduced; those made at Cedar Keys and Santa Cruz are partly reduced, and those made at the remaining stations have not yet been advanced beyond the field reductions.

Very respectfully, &c.,

WM. HARKNESS,
Professor Mathematics, U. S. Navy, of Executive Committee United States Transit of Venus Commission.

Commodore S. R. FRANKLIN, U. S. N.,
President of Transit of Venus Commission, Washington, D. C.

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REPORT

OF

THE SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR

THE YEAR ENDING JUNE 30, 1885.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1885.

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REPORT

OF THE

SUPERINTENDENT OF NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
Washington, October 5, 1885.

SIR: Pursuant to the Bureau's instructions of the 24th ultimo, I have the honor to submit herewith the report of the operations of the Naval Observatory during the past year.

Rear-Admiral S. R. Franklin, U. S. N., continued in the duties of Superintendent until the 31st March of the current year, when he was detached therefrom in order to assume command of the United States naval force on the European station. In the interim from that date until the 1st of June, 1885, Commander A. D. Brown, U. S. N., acted as Superintendent, when, under the orders of the Department, I assumed the duties of the office.

Finding everything pertaining to the organization of the institution, and the methods pursued, in as good working condition as the present means and force admit, no change has been made either in system or detail.

THE 26-INCH EQUATORIAL.

This telescope has continued in charge of Prof. A. Hall, U. S. N., who has been employed in observing the satellites of the large planets and in observation of double stars.

Though in constant use, the instrument, together with its micrometer, driving clock, and other apparatus, remains in good working order, and the dome, 43 feet in diameter, covering it, is now revolved with great ease by means of the 4 horse-power gas-engine which was connected with it in the latter part of 1884. The dome is now turned to any position required in a few minutes, and the work of observing is much facilitated. Mr. George Anderson has charge of the engine, and assists Professor Hall in the management of the dome.

The complete reduction and discussion of the observations made with this instrument have made good progress during the past year. This is due, in a great measure, to the efficient aid rendered by Lieut. W. H. Allen and Ensign J. A. Hoogewerff, U. S. N. These gentlemen have been very diligent in making the necessary computations, and have shown marked aptitude for the work.

The observations of the satellite of Neptune and those of the two outer satellites of Uranus have been discussed, and the masses of these planets deduced. These results have been published in Appendices I and II of the annual volume of the Observatory for the year 1881.

A discussion of all the observations of Iapetus, the outer satellite of Saturn, is now nearly finished, and will be ready for printing in a few weeks.

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TRANSIT CIRCLE.

This instrument is in charge of Prof. J. R. Eastman, U. S. N., assisted by Assistant Astronomers Skinner, Winlock, and Paul, and has been employed, as in the last few years, in the observations of: (1) Stars of the American Ephemeris for the determination of clock and instrumental corrections. (2) The sun, moon, and major and minor planets. (3) Miscellaneous stars, comprising those used as comparison stars in observations of minor planets and comets, and those necessary to complete the observations for the proposed catalogue of stars observed with the transit circle.

Since the last report 5,520 observations have been made. Of these, 90 were of the sun, 70 of the moon, 156 of the major planets, and 64 of the minor planets.

The labor of preparing the copy and reading the proof of the volumes for 1881 and 1882 has taken such a large portion of the time of the observers and computers that the computations for the work of 1883 and 1884 have been greatly delayed. These computations are now progressing as fast as possible with the present force.

THE 9.6-INCH EQUATORIAL.

This instrument remained in charge of Commander W. T. Sampson, U. S. N., with Prof. Edgar Frisby, U. S. N., as assistant, until October 28, 1884. Professor Frisby was placed in charge April 2, 1885.

The work of the instrument has been confined to: (1) Observations of comets, six of which have been systematically observed during the year. These observations have all been reduced to date, and published in various astronomical journals in this country and Europe; elements of Barnard's comets were computed, the first of which were published in the Astronomische Nachrichten. (2) Observations of asteroids, principally of such as could not be observed with the transit circle on account of their faintness or their position; thirty-five regular observations of asteroids were made, and twenty-one approximate positions of other asteroids obtained, so that they could readily be observed with the transit circle. (3) Occultations of stars by the moon, whenever practicable. (4) Doubtful observations of stars and asteroids made with other instruments were looked up and decided, this being probably one of the most important uses of the equatorial.

A few observations have been made of the variable star in the nebula of Andromeda, which show that the star is decreasing in brightness. Assistant Astronomer Winlock has made several observations of comets, with drawings of their physical peculiarities and changes of appearance.

THE PRIME VERTICAL INSTRUMENT.

The work of reducing the observations made in 1883–'84 by Lieut. C. G. Bowman and Ensign H. Taylor, U. S. N., for the determination of the constant of aberration, has been pursued. A selection was made of twelve stars of varying right ascension and well determined places, and the results obtained; the reduction of the remaining observations will be proceeded with as rapidly as possible.

In July of last year a communication was received from the president of the International Geodetic Conference, asking the co-operation of this Observatory with the Royal Observatory at Lisbon in the determination of the problem of the change of latitudes, the observations to be taken with the prime vertical instruments of the two observatories. Communication was opened and correspondence is still in progress with the director of the observatory at Lisbon, and preparations have been

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made to undertake the work here very soon after it is known that it will be begun at Lisbon.

ANNULAR ECLIPSE OF MARCH 16, 1885.

In February last a circular was issued by the Superintendent, giving the names of various points in the path of the annulus of the eclipse of March 16, and the approximate times of the beginning of the annular phase; this was distributed throughout the sections of the country interested, by means of the Pacific Railway companies. The Western Union Telegraph Company also had the courtesy to extend the facilities of their lines for the transmission of the noon signals on the 15th and 16th March as far west as Sacramento and Delta in California. This was successfully done, and all observers had accurate comparisons with the standard clock.

Reports were received from—
Mr. J. Blickensderfer, chief engineer, Union Pacific Railroad.
Mr. Francis D. Jones, Helena, Mont.
Mr. F. Hess, Fort Dodge, Iowa.
Mr. S. N. Griffith, Jamestown, Dak.
Mr. F. T. Taylor, Tacoma, Wash.
Mr. M. Winger, Cleveland, Ohio.
Mr. G. F. Goodhue, Bozeman, Mont.
Mr. William H. Kinnon, Bismarck, Dak.
Mr. W. W. Austin, Richmond, Ind.
Mr. William Hood, chief engineer, Central Pacific Railroad.
Mr. W. S. Palmer, Delta, Cal.
Mr. C. H. Rockwell, Delta, Cal.
Miss E. L. Muerner, Naperville, Ill.

Photographs were received from—
Mr. George L. Heath, Hastings, Mich.
Mr. —— Bayne, Grand Rapids, Mich.
Mr. George P. Lovegrove, Lakeview, Oreg.

No unusual phenomena were observed.

Observations of the first contact were made at this Observatory by Professors Hall and Frisby and Assistant Astronomer H. M. Paul. The difference of right ascensio of the second limbs of the moon and sun was observed by Lieutenant Bowman on the east transit, and by Assistant Astronomer W. C. Winlock on the west transit.

Ninety-nine photographs of the various stages of the eclipse were taken with the photo-heliographic apparatus of the Transit of Venus Commission by a party consisting of Commander Brown, Ensigns Winterhalter and Taylor, and Mr. W. F. Gardner. The exposures were made and the negatives developed by Ensign Winterhalter; one-half the plates used were coated with gelatine; the other had the Transit of Venus emulsion, being over two years old. A number of these plates have been measured by Ensigns Hogg and Taylor, and the results given to the Superintendent of the Nautical Almanac in accordance with his request.

The data will soon be published.

THE MERIDIAN TRANSIT INSTRUMENT.

Lieut. C. G. Bowman, assisted by Lieut. John Garvin, U. S. N., has remained in charge of this instrument. The work has consisted principally of daily observations and reductions for clock corrections in connection with the time service. Observations for the right ascension of the sun, moon, and major planets were taken until June of the present year, when they were discontinued. The standard clock has continued to perform well. The east transit clock has been much improved

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by an outer case with a considerable air space which has been built around it. The Kessels clock has during the present month been connected with the east transit chronograph, and as daily comparisons at the time of observation are made with it, it is expected that it will serve as a useful check upon the performance of the other clocks.

Lieut. L. L. Reamey, U. S. N., has been employed during the greater part of the year upon the reduction of the transit observations.

MURAL CIRCLE.

The work laid down in the programme for the mural circle has been transferred to the Repsold meridian circle at the Naval Academy, Annapolis, through the co-operation of Capt. F. M. Ramsay, U. S. N., the Superintendent of that institution.

Prof. S. J. Brown, U. S. N., has been engaged in putting the instrument in order and in fitting up the observatory-room for the observations which will soon begin.

CHRONOMETERS AND TIME SERVICE.

This division of the Observatory has continued in charge of Lieut. E. C. Pendleton, U. S. N.

There are at present in the chronometer-room 240 chronometers, of which 21 are ready for issue, 30 are on trial, 57 require repairs, and 132 are condemned, to be used only as backs.

During the year 39 chronometers were issued and 49 were received from naval vessels and stations. Two chronometers that were purchased from M. F. Dent, of London, for use on the Greely relief ships Bear and Thetis, were received at the Observatory. Forty-five chronometers were sent to be cleaned and repaired, and 20 remain with Messrs. T. S. & J. D. Negus, and Messrs. John Bliss & Co., of New York, and Messrs. William Bond & Son, of Boston.

Two chronometers were loaned by order of the Bureau of Navigation—1 to the Signal Office, 1 to the Department of the Interior—and 2 were condemned.

The Bureau of Navigation having notified the chronometer makers of its intention to purchase 12 new chronometers after competitive trials, the firms of T. S. & J. D. Negus, John Bliss & Co., and William Bond & Son have signified their purpose to send to the Observatory about 40 chronometers. They will be delivered during the month of December. The trials will commence January 1, 1886, and continue for six months. No chronometer will be admitted to competition that is not essentially of American workmanship.

During the past year the demands upon the time service have greatly increased. In Washington, the number of clocks of the Gardner system in the various public offices has increased from 20 to 84. Under the arrangement with the several Departments, the Observatory is held responsible for the condition of these clocks, which, with the exception of those in the Interior Department, are visited weekly, inspected, and wound. The clock circuit being largely composed of overhead wires, is subject to various interruptions and interferences by reason of its situation relative to other wires, and requires constant care and attention. The local batteries in the various buildings also require to be looked after quarterly, and an appropriation has been asked for under the head of maintenance of time service to cover these and other expenses.

In this connection it may not be amiss to add that this clock system

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is due to the inventive genius of Mr. W. F. Gardner, the instrument-maker of the Observatory. Mr. Gardner has been at considerable personal expense in perfecting this invention, which is becoming more and more valuable every day, both to the Government and the public, and it is submitted that he should receive due recognition therefor when Congress has an opportunity to look into the matter.

The plant at the Observatory has also been increased by the addition of a second transmitting clock and the purchase of electrical measuring instruments, by which the line can be tested at any time and faults detected. Their value has been shown by the detection of injuries to the Government cable on two occasions, the location of which could not otherwise have been determined. The battery requirements on account of the line have also been largely increased.

The adoption of the system of standard time created a demand for a more correct time than had been the case, and the noon signal from this point became of greater value than when the old system of local times was in vogue. To answer this demand, and also to render such service to the maritime community as they find in other countries, time-balls have been established by the Department at various points along the Atlantic sea-board, and it is intended, if the appropriation be made, to place additional ones at important commercial points. The advantage to the shipping community can hardly be overestimated. The Western Union Telegraph Company has given the use of its wires for the transmission of the necessary signals without charge. The correct time is thus given to the representatives of the Department at Boston, Mass.; Newport, R. I.; navy-yard, New York; Philadelphia, Pa.; navy-yard, Washington; Hampton Roads, Va.; Savannah, Ga.; New Orleans, La.

Three minutes before noon of each day (the busiest time of the twenty-four hours) are given up to these signals, and it is respectfully submitted that proper remuneration should be made to the telegraph company.

The branch observatory at Mare Island, which is fitted with a duplicate of the transmitting apparatus of this Observatory, has been connected with the mainland by a cable laid by the Western Union Company without any charge to the Department, and time signals are transmitted daily along the Pacific coast. A time-ball has been erected on the island for the benefit of the Vallejo shipping, and is dropped daily at noon of the one hundred and twentieth meridian. The Hydrographic Office time-ball at San Francisco is also dropped at the same instant by signal from the Mare Island Observatory.

The balls at Savannah and Hampton Roads are now hoisted daily by volunteer labor. It is respectfully submitted that a reasonable compensation should be paid for this service, which will be done from the time-service appropriation when made.

The growth of Washington has rendered the Observatory time-ball of but little account; hence in May last a proposal was made for its transfer to the central pavilion of the Navy Department. This was duly accomplished by the aid of Chief Engineer H. L. Snyder, U. S. N., the superintendent of State, War, and Navy Departments building, and since the 11th of July the ball has been dropped from the staff at that point. The one at the Observatory has been discontinued.

The total number of time-balls now dropped by this Observatory signal is eight, at the following points:

Philadelphia, Baltimore, New Orleans, at branch hydrographic of-

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fices; New York, Western Union building; Navy Department, Washington, navy-yard Washington, Hampton Roads, Savannah.

A ninth will soon be added at the torpedo station in Newport.

LIBRARY.

The library was in charge of Lieut. John C. Wilson, U. S. N., until the 30th ultimo, when, owing to ill health, he requested his detachment from the Observatory in order to take a sick leave. He was succeeded in the duties of librarian by Lieut. L. L. Reamey, U. S. N., transferred from the meridian transit instrument.

The library is increasing rapidly in bulk and value, and the lack of storage room and proper accommodations for those consulting its varied volumes becomes more apparent from year to year.

It contains, by actual count, 11,423 volumes; 2,283 pamphlets.

This is somewhat less in number of volumes than has been previously reported, but which is accounted for, in part, from the fact that in some instances paper-covered publications of two volumes when sent to the binder have been bound in one. The accessions to the library during the year have been as follows:

Volumes	441
Pamphlets	366
Total	807
Of these, there were received by exchange	579
By purchase	228

The present list of exchanges contains:

Foreign addresses	436
Domestic addresses	474

The following publications of the Observatory have been received from the Public Printer and distributed:

Programme of work for 1885.

Observations of the Minor Planets, Professor Frisby.

Circular preparatory to Observations of Solar Eclipse March 16, 1885.

Results of Observations of March 16, 1885.

Annual Volume for 1881.

Meteorological Observations, 1881.

Meteorological Observations, 1882.

Appendices I and II, Annual Volume, 1881.

The following communications from the Superintendent have been furnished for publication in the various astronomical journals:

Observations of Comet Wolf (Commander Sampson and Professor Frisby).

Observations of Hyperion (Professor Hall).

Observations of Minor Planets (Professor Frisby).

Observations of Satellites of Saturn and Companion of Sirius (Professor Hall).

Discussion of Proper Motion of Lacaille 16616 (Professor Frisby).

Observations of Comet Barnard (Professor Frisby).

The printing of the annual volumes, which had fallen far behind, has been somewhat advanced owing to the passage by Congress of a concurrent resolution for the publication of the volumes for 1881 and 1882.

The volume for 1881 has been printed and distributed as noted above, and that for 1882 is in the hands of the printer. The volume for 1883

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will be ready next spring, and it is earnestly hoped that the additional computers estimated for will be granted, in order that the observations may be reduced and published within a reasonable time after they are made.

On January 1 Professor Eastman was, at his own request, relieved of the charge of the meteorological observations, and that work was transferred to the control of the officer in charge of the library, and the observations have been taken by the watchmen as usual.

PHOTOGRAPHY.

In the programme of work proposed for the current year it was stated that the work of taking sun photographs daily would be inaugurated as soon as practicable. The work of the Transit of Venus Commission has up to this time prevented any regular system being adopted. Such work, if pursued systematically and continuously, would put this institution on a footing in this regard more nearly equal to that of the larger foreign observatories where a large mass of data has been accumulated for future measurement, computation, and discussion, forming the basis of much information of value to the student of solar physics.

For purposes of co-operation in this scientific work, photographic observations in different parts of the world being supplemental to each other, it is also desirable that this work be begun, and sooner or later it will have to be taken up here in order to keep pace with the requirements of modern astronomical research and observation. It cannot, therefore, be begun too soon.

It is eminently desirable that this Observatory possess a collection of photographs of astronomical subjects, and so be enabled to solicit exchanges from astronomers abroad that are engaged in celestial photography. But we lack the means and equipment for printing and making photographic positives that can properly be used for such purposes of exchange.

Much work is desirable to be done in photographing star clusters, nebulæ, and the spectra of sun-spots, stars, &c., and in the production of star maps by photography. Should a party from this Observatory be sent to observe the total eclipse of 1886, photographs of the phenomenon will have to be taken. The Observatory should at all times be prepared for such an occasion and have a staff drilled in photographic work, and this might be easily accomplished, as the number need not be great, and it could be made up of officers stationed here.

For all these purposes, and for work of a kindred nature, an estimate of $1,000 has been submitted, which it is hoped will receive the favorable consideration of Congress.

Through the courtesy of Professor Baird, of the Smithsonian Institution, Ensign Winterhalter has received a course of instruction in photography, and is ready to prosecute work of this character.

NEW OBSERVATORY.

I beg to renew the recommendations of my predecessors for the removal, at an early day, of the plant of the Observatory to the new site selected and purchased for such purpose in 1881.

The plans, long since prepared, have received the approval of prominent scientific men of the country, and the work can be begun as soon as the money is forthcoming; and with the funds in hand, it would take

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fully three years to erect the buildings, transfer the plant, and get everything into good working order.

The National Academy has been requested by the Department to express its opinion officially as to the advisability of proceeding promptly with the erection of the building, and it cannot be doubted that it will express itself affirmatively in the matter.

The disadvantages of the present location have been so often and so forcibly described that the subject is worn almost threadbare.

To the foresight and energy of officers of the Navy is due the inception and development of this institution. It is emphatically the child of the Navy, and the service is much interested in its welfare and in every effort to extend the sphere of its usefulness. From its humble beginning in 1838 it has now grown to be one of the most important astronomical centers in the world, and it is to be hoped that Congress will recognize the good work hitherto done by granting the means to place the institution on a still higher plane than it now occupies.

BOARD OF VISITORS.

I also beg to renew the suggestion heretofore made that a board of visitors, composed of competent persons, be appointed annually to visit the institution and inquire into its workings, with authority to suggest such changes in the methods pursued, or such new lines of investigation, as it might deem proper to recommend. Perhaps the best constitution of such a board would be a committee of Congress, acting in conjunction with a number of gentlemen of well-known attainments and authority in the scientific world.

SOLAR ECLIPSE OF 1886.

A total eclipse of the sun will occur on the 29th of August, 1886. The line of totality passes over the equatorial portion of the Atlantic Ocean, and reaches the west coast of Africa near Benguela, in latitude 12° south. This port is easy of access, and as it is the healthy season, there would be no difficulty in sending a party out in a Government vessel. The duration of the totality at this point is four minutes and forty seconds, affording a more than usually good opportunity for photographic and spectroscopic observations. The question as to the propriety of applying for an appropriation to defray the expenses of an observing party has been referred by the Department to the National Academy and a report may soon be expected. Should it be favorable, I beg to recommend that a special application be made to Congress, as the funds ought to be available by February 1, 1886, at the latest.

MISCELLANEOUS.

During the year the names of 1,408 visitors have been recorded, and 1,137 permits were issued for night visitors, for whose accommodation the small equatorial is set apart. The presence of these visitors is not allowed to interfere with the regular work of the institution, and permits are only issued for one evening in each week, with exceptional instances.

The records kept by the several observers and watchmen show that only about one night in eight is good for observing, while an exceptionally good night for astronomical work cannot be reckoned upon much oftener than once a month.

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The status of the assistant astronomers at the Observatory is a very unsatisfactory one. Their duties demand a high degree of scientific ability and long training, and their services grow more and more valuable with increase of time. Nevertheless, not only is there no provision for increase of pay, but their positions have never been assured, but have depended from year to year on the chance of an appropriation. As a consequence, they have generally soon resigned to accept more lucrative positions elsewhere, mostly directorships of observatories, or professorships of astronomy in colleges and universities. Thus this Observatory loses their services when they have become the most valuable. In the twenty-four years that the assistant astronomers have been at this institution, there have been from the corps of three, eleven resignations and only four promotions, and of the latter only one in the last twenty years, facts which speak for themselves. It is respectfully urged that the Observatory should be able to offer sufficient inducements to secure the continued services of its trained assistants; and to that end I beg to recommend that they be recognized by statute as permanent attachés of the institution, with suitable and timely provision for longevity pay. The pay these gentlemen are now receiving is not an adequate compensation for the attainments they bring to their work, nor for the diligent and valuable service they render.

The position and responsibilities of the instrument-maker are of a peculiar and exacting character. Upon him depend the adjustment and the keeping in repair and good working order of all the instruments in use at the Observatory, and it is needless to add that the demands upon his time and attention are constant and unremitting. It is therefore urged that Congress may consider favorably the increase of pay asked for in his case.

In accordance with the recommendations contained in the last report a number of sextants, old and new, have been sent here by the Bureau for examination and report. Ensign A. G. Winterhalter is in charge of this work, and it is to be hoped that the system will not be again abandoned.

TRANSIT OF VENUS, DECEMBER 6, 1882.

The work of reducing the various observations of this transit has been carried on through the year under the immediate supervision of Prof. William Harkness, U. S. N., assisted by Messrs. Joseph A. Rogers, A. S. Flint, and Asaph Hall, jr. The details of this work will be found in the appended report of Professor Harkness.

Some $30,000 worth of instruments belonging to the Transit of Venus Commission are stored here, and as they will not again be required by the Commission, I recommend that they be turned over to the Observatory for such uses as the Superintendent may judge best.

Very respectfully,

GEO. E. BELKNAP,
Commodore U. S. N., Superintendent.

Capt. J. G. WALKER, U. S. N.,
Chief of Bureau of Navigation,
Navy Department, Washington, D. C.

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UNITED STATES NAVAL OBSERVATORY,
Washington, October 3, 1885.

SIR: I have the honor to submit the following report of the work done during the past year, under my supervision, for the Transit of Venus Commission.

The assistants engaged upon the work at the beginning of the year were Messrs. A. S. Flint and A. Hall, jr. Very fortunately an opportunity presented itself last winter of temporarily securing the services of Mr. Joseph A. Rogers to finish the photographic investigations which he left incomplete when he resigned on March 1, 1883. He was reemployed on December 16, 1884. Mr. Hall resigned his position on September 15, 1885, to accept a place in the observatory of Yale College. His loss is a matter of regret to the Commission, especially at this time, when the computations upon which he was engaged are nearing completion. Messrs Rogers and Flint are still in the employ of the Commission.

At the date of my last annual report experiments were in progress to determine whether or not the heliostat mirrors undergo any change of curvature when exposed to the sun's rays. As that question is of vital importance in the theory of the horizontal photo-heliograph, it was thought desirable to make the experiments both in the heat of summer and in the cold of winter. The work was done principally by Messrs. Flint and Hall, and was completed on February 23, 1885. Owing to press of other matters the discussion of the results has not yet been undertaken.

Mr. Rogers is now engaged in writing an account both of the processes employed in preparing and developing the dry collodion emulsion plates used with the photo-heliographs in observing the transit of Venus in December, 1882, and of the experiments which were executed to determine the best method of making pyroxyline for that purpose. Whenever photographs are required which must sustain the test of accurate measurement, the collodion emulsion process offers advantages so great that every effort should be put forth to increase its general availability. Some of our recent experiments incidentally tend in that direction, and although primarily made to clear up obscure points relating to the transit of Venus work, it is hoped they will facilitate the application of collodion emulsion in future operations requiring the use of photo-heliographs. In these experiments pyroxyline has been made from flax, jute, etc., as well as from cotton, which is the form of cellulose commonly preferred.

It will be remembered that wet bromo-iodide plates, made by the bath process, were used with the photo-heliographs in observing the transit of Venus in December, 1874, and the question naturally arises whether or not the negatives then obtained are strictly comparable with those made upon dry collodion emulsion during the transit of December, 1882. For the definitive settlement of that point recourse was had to photographs of the solar spectrum. In June, 1881, a set of such photographs was made upon wet bromo-iodide bath plates of the kind used in December, 1874, and similar sets are now being made with emulsions as nearly as possible in the same condition with respect to age, etc., as those actually employed in observing the transit of December, 1882. In order to show clearly the progressive action of the solar rays upon the silver salts, each set begins with the shortest exposure capable of producing an easily legible impression, and extends to exposures two or three hundred times as great. The negatives have not yet been subjected to critical examination, but the general result seems to be that,

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while marked differences exist in the action of the spectrum upon the two classes of plates with the exposures given in the photo-heliographs, the effective rays are of substantially the same wave-length in both. The transit plates of 1874 and 1882 are therefore quite comparable in this respect, and there is no reason to apprehend systematic differences between them depending upon atmospheric dispersion. The spectrum photographs have also established the fact that the emulsion plates have a degree of sensitiveness not very different from that of bath wet plates.

Since the end of February, 1885, Messrs. Flint and Hall have been engaged pretty steadily in reducing the observations for time and latitude made at the various United States stations in December, 1882. These computations are now nearly completed, and to a considerable extent prepared for printing. It is expected that they will form Part III of the Transit of Venus Reports. No progress has been made in the reduction of the photographs during the current year, and it is not proposed to take them up again until after all the manuscript relating to time, latitude, and longitude has been prepared for the printer.

The work of printing Part II of the Transit of Venus Reports has recently been resumed, and will probably be completed at an early date. This part will form a volume of about five hundred quarto pages, and will contain the records of all observations made at the United States stations for observing the transit of 1874, together with the corresponding reductions and discussions, excepting only those relating to the photographs.

Very respectfully, &c.,

WM. HARKNESS,
Professor of Mathematics, U. S. Navy, of Executive Committee, U. S. Transit of Venus Commission.

Prof. ASAPH HALL, U. S. N.,
President of Transit of Venus Commission.

Respectfully forwarded to the Superintendent of the Naval Observatory.

ASAPH HALL,
Professor of Mathematics, U. S. N.,
President of Transit of Venus Commission.

UNITED STATES NAVAL OBSERVATORY,
Washington, September 18, 1885.

SIR: No appropriation having yet been made for the erection of a new Naval Observatory upon the site purchased therefor under the act approved February 4, 1880, I have the honor to renew the estimate which was submitted by my predecessors in 1882, 1883, and 1884, and beg to request that it may be again submitted to Congress with the approval of the Department.

In anticipation of removal to the new site no money of any moment has been expended at the present location for repairs and improvements for several years. As a consequence thereof the buildings and appurtenances are fast getting into a dilapidated condition, hardly creditable to a national institution of such prominence and character; and unless Congress, in its wisdom, see fit to grant the money, or a part of it, submitted in the estimate for the proposed new structures, then it is urged that a reasonable sum be appropriated for the purpose of improving the condition of things here at the old point.

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The sum required for the new Observatory ($586,138) is intended to cover all expenses of putting the establishment, on its removal, in perfect working condition in every way. It includes the erection of the Observatory buildings proper, quarters for the Superintendent, the observers, and others whose attendance is necessary at all times, especially during the night; the removal and remounting of the instruments, construction of roads, grading and fencing, and other details of like character.

Plans for the proposed building were prepared in 1881, under the supervision of the then Superintendent, the late Rear-Admiral John Rodgers, U. S. N. After completion they were submitted to some of the leading scientists of the country for examination, and, receiving their approval, were adopted by the Commission authorized by Congress to take cognizance of the matter. They are believed to be, in the main, all that is desirable.

The present location is unhealthy in the extreme, and those who are called upon for night service suffer more or less from malaria a good part of the time. Fogs, also, gathering over the Potomac at certain seasons of the year, frequently obstruct the observers, and many desired opportunities for astronomical work are lost in consequence. On the other hand, the terrene surroundings and influences and atmospheric conditions at the new site are very salubrious and favorable, and it is to be hoped that Congress will give such facts careful consideration when the estimate in question is laid before it.

I also submit, in connection with this subject, a communication from the late Supervising Architect of the Treasury to the Committee on Appropriations of the House of Representatives in 1882.

Very respectfully,

GEO. E. BELKNAP,
Commodore, U. S. N., Superintendent.

Capt. J. G. WALKER, U. S. N.,
Chief of Bureau of Navigation, Navy Department.

TREASURY DEPARTMENT,
OFFICE OF THE SUPERVISING ARCHITECT,
April 22, 1882.

SIR: In compliance with the request of your committee, conveyed by letter of the 12th instant, I have examined the plans and specifications for the proposed building for the Naval Observatory.

The present buildings are old and dilapidated, and the interests of the public service require that the new building should be erected as speedily as possible.

I estimate that the lowest amount that would reasonably serve for the first year's work would be about one-half of the amount proposed to be appropriated, say, $275,000.

I think, however, the Government interests would best be served by an appropriation of the entire amount estimated for the work.

Very respectfully,

J. G. HILL,
Supervising Architect.

Hon. FRANK HISCOCK,
Chairman Committee on Appropriations,
House of Representatives.

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REPORT

OF

THE SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR

THE YEAR ENDING JUNE 30, 1886.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1886.

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REPORT

OF THE

SUPERINTENDENT OF THE NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
Washington, October 20, 1886.

SIR: I have the honor to submit the following report of the operations of this establishment for the past year, in response to the Bureau's order of the 11th instant (No. 3002*a*):

PERSONNEL.

Commodore George E. Belknap (who was the Superintendent at the date of the last annual report) having been detached on the 7th of June and ordered to command the Mare Island navy-yard, I have since that date, in pursuance of the orders of the Department, performed the duties of Superintendent. Since the last report Lieutenants Pendleton, Bowman, and Garvin, and Ensigns Taylor and Hoogewerff, having completed a full tour of duty, have been detached and ordered to sea, the Observatory losing their services with regret. Ensigns Hogg and Hourigan have been likewise ordered to sea, the former after a year and the latter after a few months of service. Ensign Worthington reported for duty in April, but soon after resigned his commission.

DISTRIBUTION OF WORK.

At present the duties of the Observatory are distributed as follows:

Chronometers and time service.—Lieut. S. C. Paine and Ensign A. N. Mayer.

East transit.—Lieuts. L. C. Heilner and James H. Sears.

Inspection of instruments.—Ensign A. G. Winterhalter.

Great equatorial.—Prof. Asaph Hall and Lieut. W. H. Allen.

Transit circle.—Prof. J. R. Eastman, Assistant Astronomers A. N. Skinner, W. C. Winlock, and H. M. Paul, and Mr. William M. Brown, jr., computer.

9 6-*inch equatorial.*—Prof. E. Frisby.

Repsold circle (*Naval Academy*).—Prof. S. J. Brown, Ensign W. G. Richardson.

Library.—Lieut. L. L. Reamey.

Photography.—Ensign A. G. Winterhalter.

Instrument-maker and electrician.—William F. Gardner.

Clerk.—Thomas Harrison.

The meteorological observations are made by the watchmen (Messrs. Horigan, Cahill, and Henderson), under the supervision of the officer in charge of the library.

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Prof. William Harkness is also attached to the Observatory for special duty as a member of the Transit of Venus Commission, to which commission and its computers the Observatory affords office room.

The system of weekly reports inaugurated in 1884 is still continued, and in addition, the officer in charge of the transit circle reports the daily detail of observers for the following week. The observers on the east transit take week and week about, reporting to the Superintendent when the change is made.

PROGRAMME OF WORK.

In January last the programme of work proposed for the year was distributed to our correspondents for their information, being as follows:

The great equatorial.

(1) Observations of a selected list of double stars, such as have rapid orbital motions, or which present some other interesting peculiarity.
(5) Observations of the satellites of Saturn and Mars.
(3) Observations of some of the fainter stars in the Pleiades, to connect them with the bright ones recently measured with the Yale College heliometer.
(4) Completion of the observations begun year before last for stellar parallax, and reduction of the same.
(5) Reduction and discussion of all observations made with this instrument as rapidly as may be possible with the force available.

The transit circle.

(1) Observations of the sun daily.
(2) Observations of the moon through the whole lunation.
(3) Fifteen to twenty observations of the major planets near opposition.
(4) Five observations at least of each minor planet near opposition, when practicable.
(5) Observations of the list of miscellaneous stars.

Transit instrument.

(1) Observations daily, for time, for correction of the standard mean-time clock, and computations daily for such correction.
(2) Preparation of the observations of 1883 and 1884.

The 9.6-inch equatorial.

(1) Observations of all the minor planets whose brightness at opposition is greater than their mean brightness.
(2) Observations of comets, to determine position and physical peculiarities.
(3) Observations of occultations of stars by the moon, when of importance.
(4) Observations of variable stars.
[A photometer for this instrument has been ordered from Messrs. A. Clark & Sons; a spectroscope by Hilger is ready for attachment.]

The prime vertical transit instrument.

Observations of a selected list of stars, in conjunction with the Royal Observatory at Lisbon, whenever the latter observatory shall assign a date to begin the work.

The mural circle.

This instrument will not be in use during the year, as the Repsold meridian circle at the Naval Academy at Annapolis has been kindly placed at the disposal of the Observatory by Capt. F. M. Ramsay, for the purpose of carrying out the programme laid down for the mural circle last year. This programme is as follows:

Observations of stars down to the seventh magnitude, south of ten degrees north declination, the positions of which have not been recently determined at some northern observatory; the observing list to be formed of all stars from Gould's Uranometria Argentina visible here and not found in Yarnall's Catalogue, the Transit Circle List of B. A. C. stars, or the recent Catalogue of the Glasgow University, together with the 303 zero stars for continuation of the southern zones, and the 59 refraction stars contained in the programme of work in the Leyden Observatory. (*Vide* Vierteljahrschrift des Ast. Ges., 1881.)

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Time service and chronometers.

The time-balls at Washington, New York, Philadelphia, Baltimore, Hampton Roads, Savannah, and New Orleans will be dropped daily at noon of the 75th meridian, and the noon signals will be extended to such other places throughout the country as may be desirable, as rapidly as arrangements can be made.

The time-ball at San Francisco will be dropped daily at noon of the 120th meridian by signal from the branch observatory at the navy-yard, Mare Island.

A competitive trial of forty-three chronometers will be held, twelve to be purchased by the Bureau of Navigation.

The rating of chronometers on hand will be continued as heretofore.

[NOTE.—The time-balls at Hampton Roads and Savannah are under the direction of the Observatory; that at New York, of the Western Union Telegraph Company; the others, of the Hydrographic Office.]

Miscellaneous.

Photographs of the sun will be taken daily, when practicable, with the photo-heliograph provided for photographing the transit of Venus.

The examination of nautical instruments will continue.

Meteorological observations will be made as usual.

CHRONOMETERS AND TIME SERVICE.

During the year past chronometers have been received, cleaned, &c., as follows:

	Purchased.	Cleaned.	Issued.	Received from service.
Box chronometers	13	26	29	36
Hack chronometers	.....	14	18	3
Pocket chronometers	.....	2	.....	.....

The total number of chronometers on the books of the Observatory is 496, distributed as follows:

	Ready for issue.	Issued for service.	On trial.	Under repairs.	Loaned.	In store.	Total.
Box	36	152	16	36	4	39	283
Hack	5	65	.....	2	3	125	200
Pocket	3	1	.....	2	.....	1	7
Pocket-hack	2	.....	.....	.....	.....	4	6
Total	46	218	16	40	7	169	496

Of the box chronometers, 50 are some thirty years old, and their period of reliability must soon cease, as in most cases the cost of repairs will be too large a percentage of the price of a new and more reliable instrument. Of the hacks, 23 are entirely unfit for repairs; and the same may be said of 4 of the pocket-hacks.

Some 25 of the box chronometers now being repaired will soon be returned and placed on trial; together with those now on trial, they will be subjected to the usual tests in the chronometer and temperature rooms before issue to the service.

During October and November last 45 chronometers were subjected to these habitual tests; they performed satisfactorily, with the exception of one that was afterwards placed upon the hack list.

The time service continues to increase in popularity, and its usefulness is daily becoming more apparent to the public as the sphere of its operations is extended. The time-balls that have been established have been much appreciated, and are of great value to our shipping and commercial interests; and applications for the erection of additional time-balls at various points have been received.

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The necessity for a uniformity of time demands an accurate standard, such as is furnished by the Observatory. By act of Congress the time of the 75th meridian is the standard for the District. I respectfully suggest that Congress be asked to amend the law by adding thereto the words "as furnished by the United States Naval Observatory," so that the law and the facts may be in accord. The Gardner clocks, in connection with the Observatory-Department time-line, have continued to give satisfaction, their correction at noon furnishing a large number of people with a means of obtaining what is popularly known as "ball-time." There are some 200 of these clocks in use in the District, for the keeping in order of 123 of which the Observatory is responsible. This is a large draft upon the appropriation, which is no larger than it was before the inauguration of this system; and it is to be hoped that Congress will make the appropriation asked for under the head of "Maintenance of time service."

Time-balls in connection with the Observatory, have been dropped at New York, Philadelphia, Baltimore, Washington, Hampton Roads, Savannah, and New Orleans with regularity. The ball at New York is owned by the Western Union Telegraph Company; the others are in charge of representatives of the Department; these last are constructed of a uniform pattern, and are made in all their details after the design of Mr. Gardner, who has given much time and thought to the matter, and to whom the observatory and the public are largely indebted. The ball upon the Navy Department building has been placed in direct connection with the Observatory, instead of being as formerly upon the clock-line; this has proved advantageous in practice. A ball has also been erected recently at Wood's Holl, by the Fish Commission, and the one at the Torpedo Station, in Newport, has been placed in working order; so that there are now nine balls which are dropped by the transmitting clock of the Observatory. This clock is furnished with an automatic apparatus by which each beat of the pendulum is registered upon a sounder and transmitted when desired through an eight-point repeater to the offices of the Western Union and Baltimore and Ohio Telegraph Companies, the fire-alarm, and the Signal Service. The transmitter is compared on the chronograph with the standard mean-time clock at 11.45 a. m. daily. The error of the standard being known, it is easy to set the transmitter and send out the signal with but a slight error.

The chronometer room has been renovated for the first time in many years, and a long-needed improvement made by the insertion of a window on its north side; to guard against the effect of sudden changes of temperature this window has a double sash. An additional pier has been erected in this room, upon which it is proposed to place another mean-time clock, as a reserve in case of accident to the standard. It has not been necessary to use the reserve transmitter during the year.

The success of the time service without the District, is due almost entirely to the liberality of the Western Union Telegraph Company, over whose lines the signal is transmitted without any charge to the Government. The company has for many years given the use of its wires, for three minutes in the busiest portion of the day, as a matter of accommodation; but it is respectfully submitted that a proper remuneration should be made for this service, so that the company may be held to a strict performance of its duty. The estimate for "Maintenance of time service" is intended to cover this, as well as to pay for the labor of attending to the balls, which is now performed voluntarily.

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It would unquestionably improve the character of the service if all concerned in it could be made rigidly accountable for their share of the work.

TEMPERATURE ROOM AND COMPETITIVE CHRONOMETER TRIALS.

The temperature room has continued to perform well, and has proved its suitability for the purpose for which it was designed. Some difficulty is experienced, however, in obtaining a temperature of 45° when the air outside is above 60°, so that its use is restricted to the colder portions of the year. In addition to the 45 chronometers mentioned above as having been put through this room, there have been 45 other chronometers tried in competition, of which 13 passed the trial satisfactorily, and were purchased by the Bureau. The details of this trial, lasting from January to June, are to be found in a paper by Lieut. E. C. Pendleton, published in Appendix III to the volume for 1883. Since the close of the trial the room has been improved by the insertion of two copper ventilators at the bottom of the room communicating with the outside air, and a third near the top of the room, over the gas-jet, larger than that originally placed there. The gas-supply pipe has been enlarged, and an additional burner has been supplied to the heating apparatus.

The experience of the last trial demonstrated that great care is necessary to prevent the balance springs of chronometers from rusting. Although the humidity to which these instruments were exposed never exceeded 88.2 per cent., yet the balance springs of several were found to be rusted in a greater or less degree. Prior to the trial some of the competitors objected to the high percentage of humidity to which the room was to be raised, but as the humidity on board ship not infrequently reaches as high a point, it was not deemed too severe a test to be applied. The natural humidity of the chronometer-room for three weeks during the past summer was 83 and 84 per cent., in view of which it would appear that the test is not an unreasonable one. Although naval chronometers do not often rust, yet I am informed that a very large percentage of those in the merchant service are found rusted when put into the hands of the chronometer-makers for repairs. I would suggest as a preventive that every chronometer-box should be supplied with a baize cover, to be kept on it at all times when the instrument is not in use; a second one should be provided, and in wet weather the cover should be changed daily and dried at the galley. I recommend that such covers be supplied to all naval vessels.

In view of the difficulty of obtaining a low temperature, spoken of above, it is considered important that future trials should begin earlier in the season, and that the makers should be notified to have their chronometers ready by the 1st of November.

As the number of repaired chronometers to be tried during the coming winter will not fill all the space in the temperature-room, an offer of its facilities has been made to various chronometer-makers, it being the desire of the observatory to afford them every assistance in its power in obtaining data that will tend to the improvement of chronometers.

EAST TRANSIT INSTRUMENT.

Daily observations for time have been taken whenever the weather would permit. The performance of the standard mean-time clock has been generally satisfactory; the variations of its rate follow closely the

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variations of the barometer, though at times anomalies occur that can not be accounted for. It is believed that its performance can be still further improved by placing it in an air-tight case, and maintaining a constant barometric pressure of about 29.80 inches. Measures have been devised looking to this end.

EXAMINATION OF INSTRUMENTS.

The examination of nautical instruments has been resumed, as stated in the last report. Two hundred and twenty-one instruments of various sorts have been examined, and the necessary reports made of the results. In this way old and useless instruments have been weeded out and placed in the category of condemned stores. The appended report of Ensign Winterhalter gives the details of this work. His suggestions as to the construction of a miniature temperature-room for testing thermometers and an apparatus for testing shade-glasses are approved, and measures will be taken to carry them out if the appropriation will permit. The work of this division is one of great value to the service, and it is recommended that its operations be extended to embrace the examination of all instruments supplied to ships for use in navigation, surveying, and meteorology. The facilities afforded at the observatory for comparing thermometers with a recognized standard are such that it would seem advantageous to have all such instruments used in the various branches of the service sent here for comparison before issue.

BRANCH OBSERVATORY, MARE ISLAND.

The branch observatory at Mare Island has continued in charge of Lieut. U. R. Harris, with Lieut. Charles F. Pond as assistant. The transmitting clock (a duplicate of that here) has continued to perform well, and the time-balls at Mare Island and San Francisco have been dropped daily at noon of the 120th meridian by its signal. The public and the service are greatly indebted to the Western Union Telegraph Company for the transmission of the signals without charge, the cable laid by the company at its own expense across the Mare Island straits, enabling it to perform this work. Arrangements are also in progress for giving the time to the Sunset Telephone Company for general distribution to its patrons throughout the State of California.

On several occasions signals have been transmitted to Port Townsend, Wash., for comparison of the chronometers of the steamer C. P. Patterson, of the Coast and Geodetic Survey, a service the importance of which is much appreciated by the officers of that vessel.

The general routine of the care of the chronometers and of the time service is similar to that pursued here. The comparisons of the chronometers with the standard are made upon the chronograph by means of a short circuit-key held in the hand, the fifty-fifth, sixtieth, and fifth seconds shown by each chronometer in turn being recorded on the chronograph.

The barometers in store have been placed under comparison and the sextants have also been examined. A 5-inch equatorial, by Clark, has also been mounted temporarily, and the question of mounting a set of photoheliographic apparatus is now under consideration.

THE GREAT EQUATORIAL.

The 26-inch refractor has been used in observations of the satellites, of double stars, and of Saturn. Observations of stellar parallax have also been made. The instrument continues in good order; some work

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by Mr. Gardner has been necessary, however. No deterioration of the objective has been noticed since it was repolished ten years ago. The principal drawback is that which will hold for every large telescope, the lack of sufficiently good atmospheric conditions; on the few fine nights we have here the performance of the instrument is good.

The gas-engine for moving the dome (in charge of Mr. George Anderson) performs well; the strains on the dome do not appear to be greater than with the former hand apparatus.

The reduction and discussion of the observations made since 1873 have been continued by Lieutenant Allen and Ensign Hoogewerff, both of whom have rendered efficient service in this matter.

The observations of Iapetus, the outer satellite of Saturn, have been reduced, and the results are published in Appendix I to the annual volume for 1882. The reduction of the observations of the six inner satellites of Saturn and for stellar parallax has been completed, and the results are published in Appendices I and II to the annual volume for 1883.

THE TRANSIT CIRCLE.

This instrument has been employed in observations of stars of the American Ephemeris, of the sun, moon, and planets, and such miscellaneous stars as were necessary to complete the data for the proposed transit-circle catalogue. The whole number of observations since the last report has been 5,180.

The reductions have been proceeded with as rapidly as possible, with the inadequate force at the disposal of the Observatory, and the printer's copy of a large portion of the work for 1883 will be ready within the next month. The apparent-place reductions for 1884 are more than half done by the first computation, but are not checked. The reading of the chronograph sheets for 1885 will probably be completed within a few weeks. It has been as yet impossible to do any work on the observations made during the current year.

It is extremely desirable that the estimate submitted for three computers should receive the favorable consideration of Congress, as with the present force it is impossible to keep the work up within less than three years from date. The early completion of the proposed transit-circle catalogue is a matter of the greatest importance, and unless additional help is provided it will be several years before this can be accomplished.

THE 9.6-INCH EQUATORIAL.

This instrument has been used in the observation of comets, asteroids, and occultations of stars by the moon. One night in each week (as has been the custom for many years) has been set apart for the accommodation of visitors. The observations are reduced to date, and those for 1883 and 1884 are ready for the printer, while those for 1885 can be made ready at short notice. Some of the results have been already communicated to astronomical journals.

REPSOLD CIRCLE.

This circle, the use of which was granted by the Superintendent of the Naval Academy, as mentioned in the last report, has been put in thorough order, and the observations laid down in the programme have been begun; the work has progressed as favorably as could have been expected, and the reductions are well in hand.

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THE LIBRARY.

The library contains 11,198 volumes and 2,439 pamphlets. The accessions during the year have been 512 volumes and 156 pamphlets, a total of 668. Seven hundred and thirty-seven volumes of Congressional documents—the accumulation of several years—containing matter entirely foreign to the purposes of the library, have been returned to the House document-room.

The total number of addresses upon the issuing list is 899, of which 425 are foreign and 474 domestic.

The following publications have been received and distributed:

(1) Report of the Superintendent for 1885.
(2) Programme of work for 1886.
(3) Observations of minor planets (Professor Frisby).
(4) Appendices I, II, and III to the volume for 1882.
(5) Annual volume for 1882.
(6) Appendices I and II to the volume for 1883.

PHOTOGRAPHY.

Photographs of the sun have been taken with the photoheliographic apparatus lately belonging to the Transit of Venus Commission, whenever practicable. This style of apparatus, while answering the purposes of the commission, does not fulfill the requirements of to-day, but has been put in use for want of a better one.

As the subject of solar and stellar photography is attracting much attention in astronomical circles, it may be well to state that the plans for the new observatory provide a place for, and contemplate the eventual mounting of, a suitable photographic telescope.

PRINTING.

The volume for 1882 has been published by authority of Congress, and a resolution authorizing the publication of the volumes for 1883, 1884, and 1885 was passed at the last session. The manuscript of all these volumes is ready, except that of the transit circle, which is delayed for the reasons already explained.

In December last an order was issued requiring the submission to the Superintendent of all manuscripts intended for the official publications of the Observatory. In accordance with this order the manuscript of the volume for 1882 and its appendices was so submitted, and referred to Professor Hall for his opinion.

In order to put the matter upon a still more satisfactory basis, in July the following order was issued:

ORDER.

In the preparation of the annual volumes for the printer, the report of the Superintendent and the general introduction will be prepared in the office of the Superintendent.

Manuscript for the other portions of the volume and the appendices will be submitted to the Superintendent, as directed in the order of December 16, 1885. No manuscript will be sent to the printer unless accompanied by a letter of transmittal from the Superintendent.

Professor Hall is charged with the duty of superintending the printing, and will be regarded as the responsible editor of the volume. Should he consider that any of the manuscript requires alteration, or that it can be improved in any way, he will call the attention of the Superintendent thereto.

ALLAN D. BROWN,
Commander, Superintendent.

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The volumes for 1883 and subsequent years will therefore be supervised by Professor Hall.

Since the establishment of the Signal Service, with its trained force of observers and new and improved instruments and methods, the value to the general public of the meteorological observations made at this Observatory has been greatly decreased, and the publication of the results is deemed to be no longer essential. Accordingly, it is the intention to omit them from the annual volumes hereafter, though the observations will be continued and the results filed for examination whenever desired.

YARNALL'S CATALOGUE.

The second edition of Yarnall's Catalogue having become exhausted, Professor Frisby has been directed to perform the necessary revision preparatory to the issue of a third edition. This involves a great amount of labor, the method pursued being in substance the following: The lists of errors published from time to time by different astronomers have been carefully analyzed by reference to the annual volumes in which the observations are printed. If necessary, recourse is then had to the original record in the observing-books, extending over a period of more than thirty years; in some cases it has been necessary to refer to the chronograph sheets. If any errors are found the observations are reduced *de novo;* if no errors are found the stars are examined with the 9.6-inch equatorial and compared with those in well-known catalogues. Every catalogue in the library has been examined for names of stars noted as anonymous by Yarnall. Up to the present time a large number of errors have been discovered, many of which are, however, of but slight importance. It is hoped to have the revision completed during the next year.

ECLIPSE OF THE SUN OF AUGUST 29.

This eclipse was observed with the 9.6-inch equatorial (power 132) by Assistant Astronomer Winlock, with the following results:

First contact	Not obtained.
	h. m. s.
Last contact (Washington mean time)	18 40 39
Greenwich mean time (observed)	23 48 51
Greenwich mean time (computed)	23 48 47
Observed—computed	+ 4

The seeing was fair.

TRANSIT OF VENUS INSTRUMENTS.

In accordance with the recommendation contained in the last report, the instruments belonging to the Transit of Venus Commission have been turned over to the Observatory and placed under its charge. The immediate charge of these instruments, valued at some $30,000, is now (and practically has been for some years) in the hands of Mr. Gardner, to whose care and attention their good condition is due.

BOARD OF VISITORS.

The recommendation made annually for the last four years for the appointment of a board of visitors is respectfully renewed. It is believed that the result of the appointment of such a board would be beneficial to the Observatory in many ways.

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MISCELLANEOUS.

During the year the names of 1,853 visitors have been recorded, and 1,553 permits were issued for night visitors. The regular work of the observers is not permitted to be interfered with, except in very rare cases.

The services of the instrument-maker are of great value to the Observatory. In addition to the work upon the instruments needed from time to time, he has charge of the electrical apparatus and connections, a department of work which is constantly growing. It is respectfully urged that favorable consideration be made of the estimate for the increase of his pay, which is not now at all an adequate recompense for the skillful and diligent services which he renders.

A few much needed repairs to the buildings have been made, but the appropriation has been insufficient to repair damages to the wall, some 250 feet of which have fallen; the gaps have been stopped with a fence which serves its purpose temporarily.

The appropriation for beginning the erection of the new Observatory having been made late in the last session of Congress, the plans are undergoing a final revision, and steps are being taken to carry them into execution.

The work of reducing the observations made on the prime vertical in 1883–'84, by Lieutenant Bowman and Ensign Taylor, progressed favorably until their detachment. These gentlemen have volunteered to finish the work as they can find time from their other occupations, and the necessary material has been furnished them for the purpose.

At the request of Maj. J. W. Powell, of the Geological Survey, Assistant Astronomer Paul was detailed by the Department to assist in the observations proposed to be made on the occasion of the Flood rock explosion at Hell Gate, New York. Such necessary instruments as the Observatory possessed were also placed at the disposal of the Survey. After the explosion Mr. Paul devoted some weeks to the collection and discussion of the data obtained under the direction of the Survey, but as yet his report has not been completed.

Very respectfully,

ALLAN D. BROWN,
Commander, U. S. N., Superintendent.

The CHIEF OF THE BUREAU OF NAVIGATION,
Navy Department.

[Report of Ensign A. G. Winterhalter.]

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., October 12, 1886.

SIR: I have the honor of presenting the following report on the work done in the division of verification of instruments during the past year while under my charge.

The instruments subjected to examination may be grouped into the following classes:

A.—Sextants and octants.
B.—Thermometers.
C.—Spy-glasses.
D.—Station-pointers (three-arm protractors).
E.—Ship's clinometers.

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A.—Sextants and Octants.

The instruments of this class embrace 55 sextants and octants, on hand when I took charge of this division; 2 Hurlimann sextants, forwarded through Commander F. E. Chadwick, U. S. N., from London, England; one sextant submitted by Messrs. T. S. & J. D. Negus, New York, for examination, and examined by order of the Bureau of Navigation; also 60 sextants forwarded from the New York navy-yard, by order of the Bureau. In all, there were examined 118 sextants and 22 octants.

The examination resulted in finally dividing the instruments into two classes: (I) Sextants and octants not worth repairs; (II) sextants and octants worth repairs.

A board of survey, detailed by the Superintendent, in pursuance of an order of the Bureau, examined the instruments of Class I, and sustained the previous finding, recommending that the instruments be condemned. Upon the approval of this recommendation by the Bureau, and by its order, all of Class I were sent to the Washington navy-yard for storage, and those of Class II to the navy-yard, New York, to await repairs.

Three sextants were left at the Observatory for the purpose of carrying on certain investigations in regard to their eccentricity.

The examination of sextants and octants as at present conducted includes the verification of (1) the mirrors and shade-glasses; (2) the limb, graduation, and vernier; (3) the pivot; (4) the telescopes; (5) adjuncts usually accompanying the instruments of this class; (6) any attachment peculiar to the sextant or octant under trial.

The apparatus used for determining the eccentricity of sextants and octants is one designed by Mr. J. A. Rogers, formerly and for a long time attached to the Observatory, and it has been found useful and reliable in fixing the amount of an error to which every graduated circle, or arc, is liable, and which in a sextant, on account of its single vernier, cannot be eliminated. It is hoped that, with the permission of the Superintendent, this instrument may be fully described and its workings illustrated, so that it may become more familiar than it now is to the officers of the naval service.

With reference to the examination of the shade-glasses, I beg respectfully to invite your attention to the following statement, found in a paper by Mr. G. M. Whipple, B. Sc., superintendent, Kew Observatory:*

> It has been found that errors may exist in the shape of want of parallelism in these (dark) glasses, sufficiently large to seriously affect an observation, accurate in other respects.

My own experience agrees with that above cited, and I would respectfully recommend that an apparatus such as the one devised by Mr. Whipple, and described by him in the paper from which the quotation has been made, or one of similar character, be provided to enable the work of verification of the shade-glasses to be done with precision.

It has been found that the telescopes usually supplied to sextants are of a very inferior quality, and in future none should be supplied that do not show a decided improvement in their performance. Those telescopes accompanying the sextants examined were critically tested. The tests applied were principally the following: (1) For flaws, striæ, &c., in the lenses; (2) for chromatic aberration; (3) for internal reflection, stray light &c.; (4) for centering and correction of lenses; (5) for figure; (6) for actual performance, definition, &c.

* Proc. Roy. Soc., vol. xxv, p. 42 *et seq.*

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B.—THERMOMETERS.

The method in use at the Observatory up to January, 1886, for comparing thermometers with the Observatory standards was, in principle, that described by Prof. E. C. Pickering,* where the bulbs of thermometers to be compared are immersed in water kept at a uniform temperature by the stirring motion produced by the alternate raising and lowering of a disk perforated with a number of holes. This apparatus underwent several modifications which experience suggested, and improvements were adopted which essentially changed the character of its working and increased its utility and convenience. As finally used at the Observatory, the errors determined by the instrument were fairly reliable, but the arrangements were still deficient in convenience of manipulation and in reliability. Besides, in the case of maximum thermometers, this method, requiring the heating and then gradual cooling of the water, was impracticable. It was thought that all these deficiencies could be partly if not wholly removed by the use of the temperature-room (completed in 1883 and described by Lieut. E. K. Moore, U. S. Navy, Proceedings of the Naval Institute, vol. X, No. 2), in which chronometers undergo tests for changes of rate due to changes of temperature. The ease and certainty with which the room can be made to pass from one temperature to another, either higher or lower, suggested its superiority over other arrangements for thermometer-testing.

During the months of April and May of this year, the temperature-room having become available, four ordinary thermometers belonging to the Observatory were therein subjected to temperatures ranging ing from that of melting ice to 112° F. Together with these, 70 clinical thermometers belonging to the United States Marine Hospital Service, of which comparisons with the Observatory standards had been requested by Supervising Surgeon-General J. B. Hamilton, were subjected to temperatures ranging from 32° C. to 44° C., or, say, from 90° F. to 111° F. The clinical thermometers being graduated with a centigrade scale, and the Observatory thermometers with the Fahrenheit scale, both of the Observatory standards, centigrade and Fahrenheit, were hung in the temperature-room during the tests and used as checks on each other, as well as for purposes of direct comparison.

Both standards are of the well-known Green type and are numbered, respectively, Fahrenheit standard, J. & H. J. Green, New York, No. 6139; centigrade standard, H. J. Green, New York, No. 294.

Both standard thermometers are very sensitive to changes of temperature, the centigrade being from its dimensions even more so than the Fahrenheit. No difficulty of comparison was experienced as between the standards and the clinical thermometers, which, of course, were registering maximum thermometers. With care, also, no difficulty was experienced in obtaining a certain temperature and in keeping it constant for a reasonable time. The test was a satisfactory and delicate one throughout, and established the usefulness of the temperature-room for this kind of work.

Certain modifications are, however, considered advisable for the better prosecution of the work of thermometer-testing. With the present arrangement of the temperature-room, which renders it necessary for the observer to enter the room when heated to a high temperature in order to obtain comparisons, the injurious effects on heart and lungs of

*Phys. Manip., vol. I, p. 32.

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the observer, liable to result from a protracted stay in the room when many comparisons are to be made, and also of the change of air and temperature, on leaving the same and entering another at normal temperature, are apparent. It is, therefore, respectfully suggested that one or the other of the following arrangements for future tests be made:

(1) The conversion of the temperature-room into a dark room and the recording photographically of the temperatures as denoted by the standard and the thermometer to be compared with it.

(2) The building of a temperature-room in miniature for thermometer testing, with a glass window for observation of temperature from the outside, or with photographic appliances for automatic records, or with both.

The thermometers, as at present tested, having been compared as nearly as possible at every second degree C. of their graduation by two observers, the mean of their comparisons is adopted as the true comparison and the errors are plotted graphically for a curve of errors. From this curve the errors at exactly equidistant intervals can be readily furnished. The thermometer is, on its glass stem, marked with a hall mark (shown in the annexed cut) and with the Observatory number by means of a writing diamond. A certificate, such as that which follows, is sent with the thermometer when issued or returned after being tested.

[Certificate of inspection.]

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., June 15, 1886.

Corrections to be applied to the scale readings, determined by comparison with the standard instruments at the United States Naval Observatory.

[Thermometer No. 66; marks, (W) 310 C*; (N) 66†; date of inspection, May 15, 1886; inspectors A. D. B. and A. G. W.]

Reading.	Correction.	Reading.	Correction.
C.°	C.°	C.°	C.°
33	—0.09	39	—0.11
34	—0.07	40	—0.10
35	—0.01	41	—0.07
36	+0.01	42	—0.03
37	—0.04	43	—0.03
38	—0.12		

N. B.—The signs given (+, —) are those with which the corrections are, respectively, to be applied to the reading of the thermometer to obtain the true reading.
* Maker's mark.
† Observatory hall mark.

It is respectfully recommended that this work be made to include all thermometers usually supplied to ships, so that not only may observations made in the different branches of the work on board ship, but also observations aboard different ships be strictly comparable with each other by being referred to a common standard, that of the Naval Observatory. The value of the observations which are being conducted aboard our ships in every part of the world, will in this event be much increased. Besides, the detection of errors is comparatively easy at the Observatory, but, perhaps, impossible on board ship.

To cite a case in point, among the seventy clinical thermometers tested as above described, although nearly all were of reliable manufacture,

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one, however, had such large and irregular errors as to render it worse than useless, indeed dangerous to use. Yet a critical examination afforded no test of the thermometer until its performance in the temperature-room settled the fact of its total unreliability.

In addition to these considerations, it is obvious that the scientific value of observations made with a thermometer that has been compared with a recognized standard is greater than that of the observations made with the best constructed thermometer if not so compared.

C.—Spy-glasses.

During the year three spy-glasses were examined by order of the Bureau of Navigation, viz, (I) Elliott Bros., 449 Strand, London, double object-glass; (II) Negretti & Zambra, London, triple object-glass; (III) Negretti & Zambra, London, double object-glass.

Reports were made on these glasses, after such thorough and practical examination as a careful study suggested. It is very desirable that the Observatory possess both a dark room and the necessary appliances for thoroughly testing telescopes of all sizes, their lenses, magnifying powers, &c. As the plans for the new Naval Observatory provide for such a telescope-testing room, it is recommended that further equipment be postponed until the Observatory shall remove to its new quarters, so that all parts of the outfit may correspond to one pattern.

A report and recommendation upon eye-pieces of ship's glasses, including an enumeration of particulars deemed essential to the successful designing of a telescope for ship's uses, was also made by order of the Bureau.

D.—Station-pointers.

Of these there were three examined, and in each case a report made to the Bureau. These instruments were of the following makes: Fauth & Co., Washington, D. C.; Keuffel & Esser, New York; George Schilling, Washington, D. C.

In the examination of the above-named instruments, so useful to the hydrographer in the mechanical solution of the three-point problem, many faults were pointed out and remedies suggested, which, it is hoped, will enable the Bureau to decide upon an instrument whose utility may be enhanced by being convenient, durable, and of such precision as is required in careful surveys.

The Observatory possesses no apparatus for determining the errors of eccentricity of such instruments, and it is respectfully recommended that steps be taken to devise and construct a suitable apparatus for this purpose.

E.—Ship's Clinometer.

An improved form of ship's clinometer, the invention of Col. G. P. Evelyn, London, was examined and a report made thereon. In the examination of this instrument several improvements suggested themselves, which it was thought would render it more useful and reliable on shipboard. These improvements made a remodeling of the instrument desirable, and, therefore, drawings and specifications for a new design were submitted to the Bureau together with the report before mentioned. It is gratifying to say that these modifications have received the indorsement of the inventor, who has promised to furnish an instrument modified as recommended.

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There have, therefore, been examined during the past year the instruments below enumerated:

Résumé of instruments examined.

A.—Sextants and octants	140
B.—Thermometers	74
C.—Spy-glasses	3
D.—Station-pointers	3
E.—Ship's clinometer	1
Total	221

As this report is being written a holosteric barometer, Keuffel & Esser, New York, is undergoing comparison with the Observatory standard. For reasons akin to those indicated in the case of thermometers, it would seem desirable that all barometers, mercurial and aneroid, should be compared with a common standard before going aboard ship. Especially must this always be true of aneroid barometers, whose readings can have no value if not directly comparable with a mercurial standard barometer.

Following out some of the conclusions above noted, I take the liberty of mentioning some of the different classes of instruments, in addition to those examined during the past year, which might with advantage be sent here for verification: (1) Ordinary meteorological thermometers; (2) ordinary meteorological barometers, mercurial and aneroid; (3) maximum and minimum thermometers; (4) clinical thermometers; (5) boiling-point thermometers; (6) deep-sea sounding thermometers; (7) hydrometers; (8) anemometers; (9) rain-gauges; (10) photographic instruments, as now supplied to ships; (11) artificial horizons.

To these may be added, upon the installation of the new magnetic observatory now in process of completion, magnetic instruments of every description.

With a view of encouraging the American manufacture of instruments such as enumerated, I would respectfully recommend that makers of nautical and philosophical instruments be invited to avail themselves of the facilities of the Observatory, in such manner and under such regulations as the Superintendent may determine.

In the examination of the mechanism of the various instruments I have had the invaluable advice and assistance of Mr. W. F. Gardner, the instrument maker, who gave the same as much of his time and attention as his other duties allowed.

SOLAR PHOTOGRAPHY.

In addition to the work done, as above stated, the duty of taking a photograph of the sun at or about noon of every clear day has also devolved upon me.

This work was commenced January 11, 1886. Up to and including September 30, 1886, there have been obtained in this manner 98 negatives showing spots on the sun's surface. In the future, the number of photographs in a given period will be considerably increased, better arrangements having been made for securing photographs at any time between 10 a. m. and 2 p. m. The position of the transit-of-Venus photoheliograph is such that an exposure cannot be conveniently made at other times. Hitherto no photographs have been taken except when the sun showed spots on his disk, and then one only near noon.

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In connection with this work it may be pertinent to state that, in my opinion, the horizontal photoheliograph is not an instrument well suited for obtaining photographs of the sun's disk, certainly not in the shape in which it is now found, that which was used in photographing Venus in transit. An equatorially-mounted photoheliograph, like the one used at Kew, England, seems preferable. Not only can better photographs be obtained, showing more detail on the sun's surface, but the subsequent reading and computations connected with the work can be much facilitated. With the present instrument, entirely suitable as it may have been for the purpose for which it was designed, that of making, as above stated, a photographic record of the transit of Venus, no entirely satisfactory work has been nor can be done in solar photography.

Pursuant to an invitation addressed to the Superintendent by Frank Rede Fowke, esq., secretary of the British Solar Physics Committee, two negatives of the sun's disk showing spots on its surface, have been forwarded to that committee, South Kensington, London, S. W.

Gelatine dry-plates have been exclusively used in this work, those of Mr. John Carbutt, Wayne Junction, Philadelphia, Pa., being found perfectly reliable. The plates used are those called "B plates" by the manufacturer, and they are comparatively slow plates, but, as there is so much light to strike the sensitive film in solar work, even slower plates might at times be used with advantage.

The modern gelatine dry-plate presents so many superiorities over any other kind of plate that it has come into use everywhere, to the exclusion of all other kinds of plates, except for special kinds of work. It was formerly thought that in the processes of solar photography recourse would have to be had to the old wet-plate process, or to collodion dry-plates, such as were used at the transit of Venus. But with the present rapid advances made in every stage of the gelatine dry-plate manufacture, that plate has been adopted by all leading observatories for their work, both in solar and stellar photography. It has proved itself to be entirely reliable for measures of precision and easy of development. Its heightened sensitiveness makes it for special occasions of great value, as exposures can be made with only a moment of clear sky or with the sun, as may occur, covered with thin clouds, when the same thing would have been impossible with the old type of photographic plate.

The negatives secured during the year have been preserved, and it is respectfully recommended that arrangements be made for their measurement. Owing to want of time, it has been impossible to do more than make the exposures and develop the same, storing the negatives away for future reading and discussion.

The azimuth of the line joining the optical center of the object-glass and the center of the reticule-plate has been frequently determined by observations of the fixed stars with Stackpole Transit No. 1502; also the level or zenith distance of the center of the reticule-plate and the distance of that point from the second surface of the photographic objective. These observations, requiring considerable computation for their final reduction, are so recorded that the computation can be proceeded with whenever the reading of the plates is commenced.

Hitherto the unsilvered mirror of the photoheliograph has been used, but experiments have for a short time been in progress for the purpose of trying the effect of introducing a mirror silvered on its first surface and also to obtain an enlarged sun-picture. The size of the present image is about 4⅓ inches. It is believed that satisfactory and in some

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respects better results can be reached with an image enlarged to, say, a diameter of eight inches.

Very respectfully, your obedient servant,

A. G. WINTERHALTER,
Ensign, U. S. Navy.

The SUPERINTENDENT.

[Report of Professor Harkness, of the Transit of Venus Commission.]

UNITED STATES NAVAL OBSERVATORY,
Washington, October 14, 1886.

SIR: I have the honor to submit the following report of the work done during the past year, under my supervision, for the Transit of Venus Commission.

The assistants employed at the beginning of the year were Messrs. Joseph A. Rogers and A. S. Flint. Mr. Rogers resigned on April 1, 1886, and Mr. Herbert C. Wilson, late of the Cincinnati observatory, was engaged on July 1, 1886. Messrs. Flint and Wilson are still in the service of the Commission.

Mr. Rogers was engaged in preparing a report on the photographic work done for the Commission, under his direction, in connection with the transit of December, 1882. This report includes an account of the elaborate series of experiments made to determine the kind of pyroxyline most suitable for astronomical photography, and, as the manuscript was not quite finished when he resigned, he is completing it, without expense to the Commission, as rapidly as his other engagements will permit.

The work done by Messrs. Flint and Wilson may be summarized in connection with the stations to which it relates, as follows:

Campbell Town, Tasmania, 1874.—The places of the latitude stars and the chronometer corrections have been revised, the latitude has been recomputed, the value of the micrometer screw of the double-image micrometer used on the equatorial telescope has been redetermined, and a considerable quantity of manuscript has been prepared for the printer.

Queenstown, New Zealand, 1874.—The places of the latitude stars have been revised and the latitude is being recomputed.

Chatham Island, 1874.—The places of the latitude stars have been revised, the latitude has been recomputed, the value of the double-image micrometer screw has been redetermined, and the chronometer corrections on the day of the transit have been improved.

Cedar Keys, Florida, 1882.—The time observations have been checked.

Cerro Roblero, New Mexico, 1882.—The reduction of the time observations has been finished, the latitude observations have been revised, the difference of longitude between the station and San Francisco has been computed, and a considerable quantity of copy has been prepared for the printer.

Wellington, South Africa, 1882.—Instrumental constants have been determined, the time and latitude observations have been reduced, the difference of longitude between the station and the Royal Observatory at Cape Town has been computed, and printer's copy has been prepared.

Santa Cruz, Patagonia, 1882.—The latitude observations have been reduced, but they may yet require a small correction on account of possible change in the adopted value of the micrometer screw. The printer's copy of the time and latitude observations has been prepared.

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Santiago, Chili, 1882.—The latitude observations have been reduced, the difference of longitude between the station and the National Observatory has been determined, and some printer's copy has been prepared.

Auckland, New Zealand, 1882.—The observations for time and latitude have been reduced, the difference of longitude between the station and Burnham has been determined, and some printer's copy has been prepared.

The values of a revolution of the zenith distance micrometer screws of the meridian instruments, Stackpole & Brother, Nos. 1503, 1505, and 1507, used, respectively, at Santiago, Wellington, and Cerro Roblero, have been redetermined from observations made with the transit circle of this Observatory.

The computations for deducing the position angle and distance of Venus relatively to the sun's center, from the measures of the photographs at Washington, Cedar Keys, San Antonio, Cerro Roblero, Wellington, Santa Cruz, Santiago, Auckland, Princeton, N. J., Mount Hamilton, Cal., and New Haven, Conn., have all been revised and checked.

The chronometrical measurements for difference of longitude between the station at Santa Cruz, Patagonia, and Lieutenant-Commander Green's station, at the English church in Montevideo, have been reduced, and the result is:

$$\text{Diff. long.} = 0^h\ 48^m\ 52^s.64 \pm 0^s.15.$$

The magnetic observations made at Hobart Town, Tasmania, in February, 1875, have been reduced and discussed with the following results:

	° ′
Declination	10 02.7 east.
Inclination	−70 27.5
Horizontal force	4.545

The value of the horizontal force is expressed in foot-grain-second units; if converted into centimeter-gramme-second units it becomes 0.2096.

In conclusion, it may be well to add that the printing of Part II of the Transit of Venus Reports has progressed very slowly during the year, but it is believed that more rapid progress will be made in the immediate future.

WM. HARKNESS,
Professor Mathematics, U. S. N.,
Of Executive Committee of Transit of Venus Commission.

Prof. ASAPH HALL, U. S. N.,
President of the Transit of Venus Commission.

Respectfully forwarded to the Superintendent of the Naval Observatory.

A. HALL,
Professor Mathematics, U. S. N.,
President Commission on Transit of Venus.

Respectfully forwarded to the Chief of the Bureau of Navigation.

ALLAN D. BROWN,
Commander, Superintendent Naval Observatory.

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REPORT

OF

THE SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR

THE YEAR ENDING JUNE 30, 1887.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1887.

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REPORT

OF

SUPERINTENDENT OF NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, October 5, 1887.

SIR: In obedience to the Bureau's order of the 26th of September (No. 2995*b*), I have the honor to submit the annual report of the Observatory.

PERSONNEL.

Since the last report, the following changes have occurred, viz: Reported for duty, Capt. R. L. Phythian, as Superintendent, November 15, 1886. Commander Allan D. Brown was detached as Superintendent, and resumed duties as assistant superintendent November 15, 1886. Lieut. H. W. Schaefer reported October 25, and Lieut. Wm. P. Elliott December 18, 1886. Lieut. Wm. E. Sewell reported May 2, 1887, and was detached July 12, with orders to the Mare Island navy-yard. Ensign J. H. Rohrbacher reported January 25, and was detached February 1, with orders to special duty at the Navy Department. Lieut. B. W. Hodges reported June 20, and Ensigns A. B. Clements and V. O. Chase reported April 1 and July 25, respectively.

DISTRIBUTION OF WORK.

The work of the Observatory is at present distributed as follows:

Chronometers and time service.—Lieut. S. C. Paine and Ensign A. N. Mayer.

East transit.—Lieuts. L. C. Heilner and B. W. Hodges.

Inspection of instruments.—Lieut. A. G. Winterhalter and Ensign A. B. Clements.

Compass-houses.—Lieuts. H. W. Schaefer and Wm. P. Elliott.

Great equatorial.—Prof. Asaph Hall and Lieut. W. H. Allen.

Transit circle.—Prof. J. R. Eastman, Assistant Astronomers A. N. Skinner, Wm. C. Winlock, and H. M. Paul, and Mr. Wm. M. Brown, computer.

9.6-*inch equatorial.*—Prof. Edgar Frisby.

Repsold circle (*Naval Academy*).—Prof. S. J. Brown; Ensigns W. G. Richardson and V. O. Chase.

Library.—Vacant.

Photography.—Lieut. A. G. Winterhalter.

Instrument-maker and electrician.—William F. Gardner.

Clerk.—Thomas Harrison.

The meteorological operations are made by the watchmen (Messrs. Horigan, Cahill, and Henderson), under the supervision of the officer in charge of the library.

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Prof. William Harkness is also attached to the Observatory for special duty as a member of the Transit-of-Venus Commission, to which commission and its computers the Observatory affords office room.

PROGRAMME OF WORK.

In January last the programme of work was distributed to correspondents for their information, being as follows:

The great equatorial.

Observations of double stars will be continued. Observations of previous years will be discussed if time and force will permit.

Continuation of measurements of the fainter stars in the Pleiades. Completion of these observations if possible.

Observations of the conjunction of the five inner satellites of Saturn, with the minor axis of the ring, and the angles of position and the distances of the faint satellite Hyperion.

Reduction and discussion of the observations of former years as time and force will permit.

The small equatorial.

Observations of comets whenever possible.

Observations of stars that need to be identified for the preparation of the third edition of Yarnall's Catalogue, now in progress.

Observations of stars and asteroids for identification for the transit circle, and of such asteroids as can not be observed with that instrument.

Observations of occultations of stars by the moon whenever practicable.

The transit circle.

Completion of the observations of miscellaneous stars for the proposed Transit Circle Catalogue; concurrently with these, observations of the sun, moon, and planets.

After the completion of the above observations (which, it is hoped, will be accomplished by the 1st of March) the instrument will be dismounted for repairs, and will thereafter be used in observations of—

The sun daily.

The moon throughout the whole lunation.

The planets, major and minor.

Stars of the American Ephemeris, required for the determination of instrumental and clock corrections.

Miscellaneous stars, as may be deemed advisable.

The observations of preceding years will be reduced as rapidly as possible.

The transit instrument.

Observations for the correction of the standard mean time clock daily.

The Repsold circle (at Annapolis).

Observations of the 303 southern stars.

The 59 refraction stars of the Leiden Observatory.

Auxiliary stars of the Berlin Jahrbuch.

Time service and chronometers.

Daily comparison of all chronometers on hand.

Daily noon signals over the wires of the Western Union and Baltimore and Ohio Telegraph Companies (Sundays excepted).

Correction, daily, of the clocks upon the Observatory—Department time lines in the city of Washington.

Dropping daily (Sundays excepted) of time-balls at noon of the 75th meridian at the following points:

Wood's Holl, Mass., under the auspices of the Fish Commission.

Newport, R. I., under the auspices of the Torpedo Station.

New York city, under the auspices of the Western Union Telegraph Company.

Philadelphia, Baltimore, and New Orleans, under the auspices of the Hydrographic Office.

Washington, Hampton Roads, and Savannah, under the auspices of the Observatory.

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Time-balls will also be dropped from the branch observatory at the navy-yard, Mare Island, on Telegraph hill, San Francisco, through the branch hydrographic office, and at the navy-yard, at noon of the 120th meridian, daily (Sundays excepted).

The time service will be extended to such other points as may be deemed best, as funds will permit.

Test in the temperature room of such chronometers as have been repaired during the past year, including the plotting of their rate curves, with the necessary computations therefor.

Miscellaneous.

The examination of nautical instruments will continue.

Photographs of the sun will be taken daily, when practicable, with the photo-heliograph of Transit-of-Venus Commission pattern.

Meteorological observations will be made as usual.

THE GREAT EQUATORIAL.

This instrument is in good working order. The dome and shutters and the apparatus for moving the dome are also in good condition.

During the past year observations of the outer planets have been made, and a few observations of the planet Venus when near elongation. Observations of some of the principal double stars have been continued as in former years. The observer hopes soon to undertake again the observation of a list of double stars for the comparison of constant errors in such measures.

For several years past particular attention has been given to the appearances of Saturn's ring, the shadows, and the ball of the planet. Some drawings have been sketched, and it is expected that these will be ready for publication during the coming year, together with notes on Saturn by various observers since the mounting of this telescope.

The dimensions of the ring have been measured during several past oppositions for the purpose of comparison with former measures.

Lieut. Wm. H. Allen has continued to assist in the reduction and discussion of the observations made with this instrument, and has taken part in the observations.

The gas-engine for moving the dome is in charge of Mr. George Anderson. There has been no hindrance to work on account of this method of moving the dome, and the use of the engine is a great relief from the former method by hand, which had become very laborious.

THE TRANSIT CIRCLE.

The transit circle was employed on observations of stars of the American Ephemeris, the sun, moon, and planets, and such miscellaneous stars as were necessary to complete the data for the Star Catalogue.

From October 14, 1886, to date, the whole number of observations with the transit circle was 2,640. Of these, 69 were of the sun, 51 of the moon, 122 of the major planets, 8 of the minor planets, and 3 of comets.

The observations for 1885 are ready for the apparent place-sheets, and will be taken in hand as soon as the computer can be spared from the mean place reductions of 1884. But little work has been done on the observations for 1886.

It is impossible to bring up properly the computing and copying now in arrears without a greater force of experienced computers. In this connection I respectfully urge that the additional computers asked for in the estimates for the coming fiscal year be appropriated for.

THE 9.6-INCH EQUATORIAL.

This instrument has been used in the observation of comets, occultations of stars by the moon, and anonymous stars in Yarnall's Catalogue.

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One night in each week has been set apart for the accommodation of visitors.

Forty four observations of comets have been made, and three occultations have been observed; they are all reduced to date, and can soon be made ready for the printer.

The observations of comets have all been sent to astronomical journals for publication.

The revision of Yarnall's Catalogue is neary completed. Every anonymous star in the catalogue has been carefully examined and compared with the observing books and with all known existing catalogues; the mistakes have all been corrected, and when necessary for the purpose of verification the stars have been re-observed with the equatorial.

Over 2,000 of these anonymous stars have been examined; 1,571 have been identified and named from other catalogues; 842 corrections have been made, and 72 stars have been re-observed.

The work of examining all the other stars for the purpose of detecting small mistakes is progressing favorably, and it is believed that the whole work will very soon be ready for the printer.

CHRONOMETERS AND TIME SERVICE.

Chronometers have been received, cleaned, issued, etc., during the year, as follows:

	Cleaned.	Issued.	Received from service.	Condemned.
Box chronometers	32	23	21	5
Hack chronometer	4	8	4	.....
Pocket chronometers	2	.....	.....	.....
Watches	.....	.....	3	.....

The following disposition has been made of chronometers belonging to the Navy:

	Issued.	On trial.	Under repairs.	Awaiting repairs.	Loaned.	Ready for issue.
Box chronometers	149	5	45	24	3	52
Hack chronometers	68	.....	.....	128	3	6
Pocket chronometers	1	1	.....	1	.....	4
Pocket hack chronometers	.....	.....	.....	4	.....	2
Watches	.....	.....	.....	4	.....	.....

Of these, 29 box, 7 hack, and 2 pocket hack chronometers are at the observatory at Mare Island ready for issue to ships in the Pacific. Forty-nine of the box chronometers have been in use over thirty years, and will probably soon be placed on the "hack" list; they should be replaced as soon as practicable. Of the small number awaiting repairs, more than half will probably fail to pass successfully the examination and trial.

The temperature room was in use from December 10, 1886, to April 12, 1887. Forty box chronometers and 1 pocket belonging to the Navy, and 4 box chronometers belonging to Bond, of Boston, and Heinrich, of New York, passed through the trial, all but 4 successfully. (See Lieutenant Paine's report of temperature trial, July 8, 1887, which is appended—A.)

During the summer the temperature room has undergone some changes which, it is believed, will add to its efficiency. The ice-box

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has been removed to the top of the house, the space between the roof and the ceiling of the room has been packed with sawdust, 6 inches more of sawdust packed about the sides, which have also been lined with thick paper, the door and window have been doubled, and the boiler has been changed for a smaller heating apparatus, which it is believed will give the necessary amount of heat with less danger of fouling, and which, as far as it has been tried, works satisfactorily.

Owing to the irregularity of the time signals received over the Western Union wires, the time ball at Newport has been discontinued. The ball at Wood's Holl has also been dropped very irregularly, otherwise the time-ball service has been satisfactory. Time has been sent out daily at noon over the Western Union and Baltimore and Ohio wires, and only on one occasion did they fail to receive the noon beat. The greatest error transmitted amounted to 1.03^s; the average error was 0.16^s.

The clock line now controls 249 clocks in Government buildings, and 33 outside. Owing to storms, lightning, and other accidental disturbances, there have been numerous breaks in this line, but as a rule the line was repaired before noon. On three days, however, none of the clocks were corrected, and on six other days but a portion of them. The Gardner apparatus in clocks and time balls continues to work satisfactorily.

EAST TRANSIT INSTRUMENT.

Daily observations, when practicable, have been taken for the correction of the standard mean-time clock; 231 observations with a total of 1,645 transits were made. The performance of the standard clock is very satisfactory; changes of temperature affect the rate but slightly; the variations of its rate follow so closely the variations of the barometer that during the year the greatest error in the assumed clock correction was 0.59^s, after an interval of four days without observations, and only four times the error amounted to 0.5^s. An additional mean-time clock (Howard No. 626) was put in circuit, and comparisons taken since May 8 show a satisfactory performance. The sidereal clocks, with the exception of the Kessel clock, are performing well. The condition of the east transit instrument is good.

EXAMINATION OF INSTRUMENTS.

This division has been under the general supervision of the assistant superintendent, Commander A. D. Brown, whose report is appended (B).

COMPASS HOUSES.

These were transferred to the care of the Observatory on June 18, 1887.

In House No. 1 are located the following instruments:

Large declination magnetometer with transit telescope for reading (Fauth & Co.); Kew unifilar magnetometer (Elliott Bros., 42); dip or inclination circle (Dover, Charlton, Kent, Circle No. 85).

In the basement of House No. 2 is located the set of self-recording magnetographs of the Kew pattern. This instrument is in adjustment, and determinations of the scale coefficients have been made. The temperature coefficients will be obtained from the curves themselves, after a sufficient series has been tabulated.

A daily determination of the absolute declination will be made from the reading of the large magnetometer for comparison with the declination magnetograph, and the weekly determination will be made from

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readings with magnet direct and inverted. The horizontal force and inclination will be determined weekly.

REPSOLD CIRCLE AT ANNAPOLIS.

The observations with this instrument have been largely confined to the "303 south stars" for the continuation of the southern zones. In all 3,300 observations have been made, not including observations for instrumental constants. The reduction of these observations is nearly completed. There remains yet to be done some work in the reduction of right ascensions and the application of systematic differences in declination to reduce the position to the Auwers system.

THE LIBRARY.

The library contains 11,532 volumes and 2,569 pamphlets. The accessions during the year have been 334 volumes and 130 pamphlets; a total of 464.

The number of addresses upon the issuing (exchange) list is 931, of which 425 are foreign and 506 domestic.

The following publications have been issued:

(1) Appendix III to the volume for 1883.
(2) Report of the Superintendent, 1886.
(3) Programme of Work for 1887.
(4) Refraction tables, U. S. Naval Observatory.

INTERNATIONAL ASTRONOMICAL CONGRESS AT PARIS.

The Observatory having been invited to participate in the proceedings of the congress which was to meet at Paris on the 16th of April, 1887, Lieut. A. G. Winterhalter was, on the 19th of the preceding month, detailed by the Department to attend upon its sessions, and he was present as a representative of the Observatory. Subsequently that officer, under the orders of the Department, visited Nice, Genoa, London, Brussels, Copenhagen, Kiel, Hamburg, and other places for the purpose of collecting information useful to the Observatory. At intervals during his absence Lieutenant Winterhalter has transmitted interesting and valuable communications, which, upon his return, will be embodied in the full report he will then make.

NEW NAVAL OBSERVATORY.

The plans for the new Naval Observatory which are being prepared by Mr. Richard M. Hunt, of New York, are nearly completed and will be submitted for approval at an early day. As soon as practicable, after the acceptance of the plans, work on the Observatory will be begun.

MISCELLANEOUS.

The names of 1,659 visitors have been recorded during the year, and 1,578 permits for night visitors have been issued.

A memorandum kept concerning the state of the "seeing" on each night shows that there were 168 nights on which there was no "seeing," 113 on which it was poor, 63 on which it was fair, but 19 on which it was good, and only 2 on which it was very good.

Very respectfully,

R. L. PHYTHIAN,
Captain, U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF NAVIGATION,
Navy Department.

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APPENDIX A.

[Report of Lieut. Sumner C. Paine.]

U. S. NAVAL OBSERVATORY,
Washington, July 8, 1887.

SIR: I have the honor to submit the following report of the trial of chronometers for the year 1886–'87:

The chronometers remained in the temperature room from December 16, 1886, to April 12, 1887, during which time they were subjected to temperatures varying from 47° to 90°, and to hygrometric conditions from 47.1 per cent. to 80.2 per cent. After removing them from the temperature room they were run in natural temperatures until July 21, 1887.

The hygrometric test, like the tests of previous years, developed the fact that no general rule can be laid down for the performance of chronometers subjected to different degrees of moisture. Of the 41 box and pocket chronometers on trial, 17 box gained at 80.2 per cent. and lost at 47.1 per cent; 9 box and 1 pocket lost at 80.2 per cent. and gained at 47.1 per cent.; 8 box lost at both 80.2 and 47.1 per cent., and 6 box gained at both percentages; 25 box and 1 pocket returned to original rates during the last week of the test; 9 box returned to original rates within 0.5^s; 10 box ultimately regained original rates, and 5 box changed rate slightly, probably owing to "acceleration."

The performance of the following chronometers was unsatisfactory: 2,149 Bliss, 3,276 Charles Frodsham, 259 James Munroe (Fosler), and 466 Crisp. The first two were resprung last year and should be returned to the firms who repaired them. I would recommend that the Munroe and Crisp be surveyed with a view to condemn them for use as sea-going chronometers.

I inclose a table showing the performance of the chronometers throughout the trial.

Very respectfully,

SUMNER C. PAINE,
Lieutenant, U. S. Navy, in charge of Chronometers.

Capt. R. L. PHYTHIAN, U. S. Navy,
Superintendent U. S. Naval Observatory.

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Record of trial of repaired chronom

Explanation of abbreviations in first column: [Bl., repaired by John Bliss & Co.

	Time		*Dec. 16 to Dec. 23.	Dec. 24 to Dec. 31.	Jan. 5 to Jan. 12.	Jan. 13 to Jan. 20.	Jan. 21 to Jan. 28.
	Temperature		47°. 09	54°. 96	69°. 98	84°. 95	89°. 97
	Hygrometer		70. 2	69. 2	70. 2	69. 9	69. 5
	Chronometer maker.	*Chron. No.*					
N.	T. S. & J. D. Negus	1615	+0 319	+0. 417	+0. 107	+0. 340	+0. 007
Bl.	James Munroe (Fosler)	264	−1. 753	−1. 047	−0. 464	−0. 981	−1. 221
N.	T. S. & J. D. Negus	1215	−2. 396	−1. 511	−0. 679	−1. 053	−1. 793
Bl.	James Munroe (Fosler)	262	+1. 819	+1. 596	+1. 429	+1. 733	+2. 350
Bo.	Wm. Bond & Son	290	−0. 181	+0. 524	+0. 429	−0. 053	−1. 007
N.	T. S. & J. D. Negus	1447	−1. 039	−0. 261	−0. 250	−0. 053	−0. 543
N.	Do	1339	−1. 146	−0. 011	+0. 679	+0. 019	−0. 757
N.	Do	1442	−0. 896	+0. 024	−0. 179	−1. 124	−1. 721
N.	Do	729	−2. 324	−1. 261	−1. 393	−2. 160	−2. 936
N.	Do	1126	−1. 324	−0. 547	−0. 143	−0. 803	−1. 471
N.	Do	259	−1. 753	−2. 226	−1. 964	−2. 553	−1. 971
N.	Do	1408	−2. 396	−1. 369	−1. 179	−1. 946	−3. 079
N.	Do	1195	−1. 539	−0. 476	−0. 500	−1. 339	−2. 186
Bo.	Barraud	2609	−1. 574	−0. 190	+1. 000	+0. 733	−0. 079
Bo.	Dent	2684	+0. 140	+1. 096	+1. 500	+0. 233	−0. 614
N.	T. S. & J. D. Negus	1094	−1. 896	−0. 547	+0. 607	+0. 447	−0. 150
N.	Do	1311	−0. 324	+1. 346	+1. 608	+0. 661	−0. 293
N.	Do	1459	−0. 860	−0. 047	+0. 786	+0. 447	−0. 257
N.	Do	1464	−2. 574	−1. 547	−0. 857	−1. 696	−2. 471
Bo.	Wm. Bond & Son	293	−1. 681	−0. 190	+1. 500	+1. 947	+1. 564
Bl.	James Munroe (Fosler)	251	+0. 319	+1. 131	+0. 607	+0. 804	+0. 921
N.	T. S. & J. D. Negus	734	−2. 110	−1. 154	−0. 786	−1. 696	−2. 329
N.	Do	1630	−2. 217	−0. 619	+0. 500	−0. 017	−0. 364
N.	Do	953	−0. 039	+0. 846	+1. 250	−0. 196	−1. 329
Bo.	Wm. Bond & Son	232	−0. 539	+0. 381	−0. 357	−1. 124	−2. 329
Bl.	John Bliss & Co	2825	−1. 967	−1. 119	−1. 393	−0. 910	−0. 971
Bl.	Do	2149	−1. 253	−0. 190	+0. 893	+0. 340	−0. 507
Bl.	M. F. Dent	25568	−0. 967	+0. 060	+1. 214	+1. 019	+0. 707
Bo.	Charles Frodsham	2831	−1. 646	−0. 797	−0. 286	−1. 446	−2. 114
N.	T. S. & J. D. Negus	959	−1. 360	−0. 154	−0. 321	−2. 267	−3. 079
Bo.	Poole	3381	−3. 646	−2. 404	+0. 250	+0. 233	−0. 043
N.	T. S. & J. D. Negus	1256	−3. 146	−1. 904	−0. 536	−1. 017	−1. 829
Bo.	Wm. Bond & Son	307	+3. 104	+3. 881	+2. 464	+1. 840	+1. 136
Bo.	Charles Frodsham	3306	−2. 717	−1. 726	−0. 714	−0. 553	−1. 007
Bl.	John Bliss & Co	2817	−4. 681	−4. 261	−3. 643	−2. 731	−3. 114
N.	T. S. & J. D. Negus	1145	−2. 360	−1. 333	+0. 179	−0. 624	−1. 329
Bl.	W. B. Crisp	466	−0. 574	+0. 381	+0. 857	+0. 304	−0. 579
N.	T. S. & J. D. Negus	1453	−3. 360	−2. 297	−0. 714	−1. 696	−2. 757
Bo.	D. McGregor	K 2009	−0. 253	−0. 369	−0. 821	−2. 660	−4. 864
Bo.	Charles Frodsham	3276	+1. 353	+2. 417	+2. 929	+2. 697	+2. 671
N.	T. S. & J. D. Negus	3699	−1. 074	+0. 096	+0. 536	−0. 124	−0. 936

* December 16 to April 2;

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eters, December, 1886–June, 1887.

Bo., repaired by William Bond & Son; N., repaired by T. S. & J. D. Negus.]

Jan. 29 to Feb. 5.	Feb. 6 to Feb. 13.	Feb. 15 to Feb. 22.	Feb. 24 to March 3.	March 4 to March 11.	March 12 to March 19.	March 20 to March 27.	March 28 to April 4.	April 5 to April 12.	Relative number.
85°. 08	70°. 05	54°. 98	47°. 09	70°. 00	70°. 03	70°. 02	70°. 02	70°. 49	
70. 3	69. 3	70. 2	68. 0	68. 7	80. 2	70. 9	47. 1	70. 4	
+0. 207	+0. 663	+0. 733	+0. 854	+1. 101	+0. 741	+1. 069	+0. 753	+0. 573	1
−1. 257	−0. 873	−0. 981	−1. 503	−0. 327	+0. 349	−0. 074	−0. 676	−0. 106	2
−1. 257	−0. 873	−1. 589	−2. 289	−0. 577	+0. 063	−0. 574	−0. 569	−0. 570	3
+1. 957	+2. 056	+2. 233	+2. 390	+2. 101	+2. 134	+1. 604	+0. 753	+1. 394	4
−0. 507	+0. 127	−0. 160	−0. 610	−0. 006	+0. 277	+0. 211	−0. 354	+0. 430	5
−0. 186	−0. 444	−0. 624	−1. 324	−0. 327	−0. 187	−0. 074	−0. 390	−0. 249	6
−0. 221	+0. 163	−0. 589	−1. 253	+0. 566	+0. 563	+0. 604	+0. 431	+0. 537	7
−1. 150	−0. 337	−1. 017	−1. 253	−0. 684	−0. 366	−0. 574	−0. 390	−0. 713	8
−2. 614	−1. 980	−2. 553	−3. 289	−2. 041	−2. 223	−1. 967	−2. 104	−1. 891	9
−0. 757	+0. 199	−0. 910	−1. 896	−0. 399	−0. 651	−0. 324	−0. 533	−0. 499	10
−2. 186	−2. 087	−2. 481	−2. 039	−1. 291	−1. 116	−1. 217	−0. 926	−1. 927	11
−2. 579	−1. 623	−2. 017	−3. 003	−1. 506	−1. 294	−1. 289	−1. 533	−1. 284	12
−1. 757	−0. 909	−0. 410	−1. 181	−0. 827	−0. 759	−0. 539	−1. 211	−0. 820	13
+0. 136	+0. 377	−0. 660	−1. 753	+0. 744	+0. 813	+0. 890	+0. 753	+0. 823	14
+0. 029	+1. 341	+1. 233	+0. 640	+1. 709	+1. 349	+1. 497	+2. 039	+1. 644	15
+0. 314	+0. 734	+0. 090	−1. 574	+0. 709	+1. 134	+0. 890	+0. 110	+0. 716	16
+0. 314	+1. 663	+1. 411	+0. 533	+1. 780	+1. 099	+1. 497	+1. 896	+1. 716	17
+0. 064	+0. 05[illegible]	−1. 089	−1. 717	+0. 637	+0. 599	+0. 461	+0. 217	+0. 787	18
−2. 007	−1. 337	−2. 303	−3. 181	−1. 077	−0. 866	−0. 967	−1. 497	−1. 141	19
+1. 779	+1. 591	+0. 090	−1. 146	+1. 494	+1. 706	+1. 569	+1. 030	+1. 251	20
+0. 493	+0. 199	+0. 733	−0. 289	+0. 173	−0. 330	−0. 181	+0. 003	−0. 213	21
−1. 971	−0. 659	−1. 553	−2. 396	−1. 113	−0. 937	−0. 574	−0. 747	−0. 713	22
+0. 136	+0. 591	−0. 660	−1. 574	+0. 566	+0. 277	+0. 247	+1. 074	+0. 287	23
−0. 614	+0. 770	+0. 411	−0. 896	+0. 851	+0. 563	+0. 211	+0. 360	+0. 037	24
−1. 864	−1. 123	−1. 410	−1. 967	−0. 541	−0. 723	−0. 646	−0. 676	−0. 534	25
−1. 114	−1. 587	−1. 303	−2. 146	−1. 613	−0. 509	−0. 503	−1. 319	−0. 356	26
−0. 114	+0. 841	−0. 339	−0. 824	+0. 994	+1. 670	+1. 640	+1. 360	+1. 859	27
+0. 814	+1. 734	+0. 376	−0. 717	+2. 244	+2. 349	+2. 426	+1. 753	+2. 216	28
−1. 686	−1. 087	−1. 624	−2. 431	−1. 006	−1. 901	−1. 181	+0. 789	−0. 891	29
−2. 507	−1. 087	−1. 339	−1. 789	−0. 577	−1. 151	−0. 717	−1. 176	−0. 570	30
+0. 171	+0. 234	−1. 231	−2. 396	−0. 256	−0. 544	−0. 431	−0. 211	−0. 356	31
−1. 364	−0 623	−2. 267	−3. 396	−0. 399	−0. 794	−0. 824	−0. 640	−0. 391	32
+1. 921	+2. 913	+2. 876	+2. 497	+2. 780	+3. 241	+2. 854	+4. 217	+3. 073	33
−1. 079	−1. 909	−3. 624	−4. 646	−1. 756	−1. 366	−1. 431	−1. 497	−1. 606	34
−2. 507	−2. 837	−3. 553	−3. 860	−2. 541	−1. 366	−1. 074	−1. 961	−1. 570	35
−0. 793	+0. 341	−1. 231	−1. 753	+0. 209	+0. 063	+0. 319	−0. 033	+0. 144	36
−0. 543	−0. 194	−2. 124	−2. 396	−0. 077	−0. 044	−0. 360	+0. 074	−0. 213	37
−2. 329	−1. 551	−2. 874	−3. 824	−1. 363	−1. 009	−1. 039	−1. 783	−1. 320	38
−4. 079	−2. 587	−1. 589	−1. 539	−1. 791	−1. 544	−1. 646	−1. 354	−1. 963	39
+1. 850	+0. 806	+0. 697	+2. 176	+3. 601	+3. 134	+3. 426	+3. 217	+1. 073	40
−0. 579	+0. 734	+0. 304	−0. 967	−0. 149	−2. 901	−2. 181	−0. 961	−0. 106	41

in temperature room.

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Record of trial of repaired chronometers,

Explanations of abbreviations in first column: Bl., repaired by John Bliss & Co.;

	Time		*April 12 to April 19.	April 19 to April 26.	April 26 to May 3.	May 3 to May 10.	May 10 to May 17.
	Temperature		64°.11	61°.02	64°.69	73°.86	71°.96
	Hygrometer		66.4	65.8	67.0	69.6	69.0
	Chronometer maker.	*Chron. No.*					
N.	T. S. & J. D. Negus	1615	+1.537	+1.543	+1.593	+1.190	+1.256
Bl.	James Munroe (Fosler)	264	−0.606	−0.600	−0.514	−0.274	−0.351
N.	T. S. & J. D. Negus	1215	−0.820	−0.921	−0.729	−0.631	−0.387
Bl.	James Munroe (Fosler)	262	+1.609	+1.686	+1.700	+1.690	+1.934
Bo.	Wm. Bond & Son	290	+0.501	+0.436	+0.450	+0.619	+0.791
N.	T. S. & J. D. Negus	1447	−0.391	+0.007	−0.086	+0.440	+0.434
N.	Do	1339	+0.573	+0.721	+1.057	+1.154	+1.184
N.	Do	1442	−0.249	+0.507	+0.950	+0.261	+0.113
N.	Do	729	−1.820	−1.921	−1.836	−2.167	−2.280
N.	Do	1126	−0.391	−0.386	−0.407	−0.131	−0.101
N.	Do	259	−0.713	−1.421	−0.800	−0.846	−0.851
N.	Do	1408	−1.677	−1.707	−1.514	−1.524	−1.494
N.	Do	1195	−0.320	−0.029	−0.014	−0.703	−0.673
Bo.	Barraud	2609	+0.537	+0.400	+0.700	+0.976	+0.970
Bo.	Dent	2684	+1.930	+2.079	+2.236	+1.904	+2.006
N.	T. S. & J. D. Negus	1094	+0.251	+0.150	+0.521	+0.833	+0.863
N.	Do	1311	+2.109	+2.150	+2.200	+2.119	+2.149
N.	Do	1459	+0.430	+0.507	+0.879	+1.297	+1.220
N.	Do	1464	−1.499	−1.600	−1.371	−1.167	−1.316
Bo.	Wm. Bond & Son	293	+0.930	+0.614	+0.950	+1.761	+1.863
Bl.	James Munroe (Fosler)	251	+0.180	+0.936	+1.307	+0.476	+0.470
N.	T. S. & J. D. Negus	734	−0.284	−0.886	−0.800	−1.060	−0.923
N.	Do	1630	+0.537	+0.650	+0.664	+0.726	+0.756
N.	Do	953	+0.644	+0.721	+0.771	+0.654	+0.827
Bo.	Wm. Bond & Son	232	−0.677	−0.457	−0.229	−0.274	−0.351
Bl.	John Bliss & Co	2825	−0.784	−0.707	−0.729	−1.181	−1.030
Bl.	Do	2149	+0.966	+1.329	+1.807	+1.654	+1.541
Bl.	M. F. Dent	25568	+1.823	+1.543	+1.807	+2.154	+2.006
Bo.	Charles Frodsham	2831	+0.073	+0.400	+0.557	+0.011	−0.066
N.	T. S. & J. D. Negus	959	−1.070	−0.957	−0.871	−1.203	−1.209
Bo.	Poole	3381	−0.141	−0.279	+0.057	+0.226	+0.291
N.	T. S. & J. D. Negus	1256	−1.106	−1.493	−1.407	−0.417	−0.423
Bo.	Wm. Bond & Son	307	+3.787	+3.686	+3.629	+2.083	+2.327
Bo.	Charles Frodsham	3306	−1.799	−2.386	−1.764	−1.096	−1.244
Bl.	John Bliss & Co	2817	−2.034	−2.314	−2.229	−1.667	−1.744
N.	T. S. & J. D. Negus	1145	−0.070	−0.136	+0.164	+0.226	+0.256
Bl.	W. B. Crisp	466	−0.641	−1.029	−0.943	−0.524	−0.601
N.	T. S. & J. D. Negus	1453	−1.749	−1.993	−1.764	−1.167	−1.423
Bo.	D. McGregor	K 2009	−2.034	−1.671	−1.657	−2.096	−2.101
Bo.	Charles Frodsham	3276	+3.573	+3.686	+3.629	+3.690	+3.970
N.	T. S. & J. D. Negus	5699	+0.073	−0.457	+0.343	+1.369	+1.327

* April 12 to June 21;

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December, 1886—*June*, 1887—Continued.

Bo., repaired by Wm. Bond & Son; N., repaired by T. S. & J. D. Negus.

May 17 to May 24.	May 24 to May 31.	May 31 to June 7.	June 7 to June 14.	June 14 to June 21.	Temperature of compensation.	Temperature constant.	First trial Number.	Final trial Number.	Relative number.
74°.79	72°.87	71°.80	72°.37	79°.21					
70.1	71.	71.7	73.1	71.					
+1.276	+1.359	+1.444	+1.137	+1.321	99.698	+.000170	7.376	8.3364	1
−0.296	−0.391	−0.306	−0.291	−0.500	69.001	−.00177	7.756	8.5954	2
−0.367	−0.356	−0.377	−0.113	−0.429	72.564	−.00255	11.025	12.0651	3
+1.954	+1.823	+1.944	+1.959	+2.286	71.875	+.000609	10.949	12.1792	4
+0.811	+0.680	+0.087	−0.113	−0.107	64.690	−.00145	10.069	12.2591	5
+0.490	+0.394	+0.587	+0.387	+0.571	51.810	+.000296	10.763	12.4927	6
+1.204	+1.180	+1.266	+1.244	+1.107	71.192	−.00275	11.517	12.6569	7
−0.831	−0.463	−0.377	−0.470	−0.679	65.684	−.00248	10.564	13.7538	8
−2.081	−2.177	−1.949	−1.684	−1.714	66.080	−.00204	12.956	14.3462	9
−0.117	+0.394	+0.230	+0.066	−0.214	69.740	−.00347	14.791	15.6509	10
−0.796	−0.820	−1.663	−1.399	−0.750	69.811	−.00149	13.283	15.8326	11
−1.439	−1.463	−1.199	−1.327	−1.571	66.286	−.00256	15.612	16.6316	12
−0.760	−0.641	−0.591	−0.720	−1.000	55.792	−.001295	16.055	17.2749	13
+1.061	+1.037	+1.123	+1.101	+1.071	74.713	−.00303	17.456	17.9260	14
+1.954	+2.180	+2.266	+2.224	+1.929	64.973	−.00343	18.011	19.0110	15
+0.811	+0.894	+0.873	+0.923	+0.750	73.836	−.00263	18.272	19.0523	16
+1.990	+2.037	+1.980	+1.887	+1.393	65.231	−.00312	18.697	19.3968	17
+1.419	+1.251	+1.266	+1.137	+1.286	75.345	−.00256	18.335	19.5448	18
−1.296	−1.177	−1.056	−1.149	−1.107	70.341	−.00351	18.951	20.0111	19
+2.061	+1.859	+1.944	+1.923	+2.107	81.263	−.00282	20.212	21.0921	20
+0.240	+0.430	+0.409	+0.066	+0.500	72.747	+.00171	18.636	21.1760	21
−1.010	−0.891	−0.699	−0.684	−0.536	67.921	−.00386	19.513	21.3930	22
+0.597	+0.323	+0.301	+0.280	+0.250	73.151	−.00369	21.227	22.8167	23
+0.811	+0.644	+0.623	+0.530	+0.321	65.674	−.00399	24.629	25.7985	24
−0.367	−0.427	−0.341	−0.399	−0.679	56.085	−.00117	24.788	26.0181	25
−1.224	−1.034	−0.627	−0.684	−0.500	68.016	+.00168	25.593	27.1628	26
+1.847	+1.716	+1.587	+2.173	+2.071	71.492	−.00418	25.204	27.6743	27
+1.954	+2.001	+2.266	+2.316	+2.000	72.881	−.00402	27.183	28.0329	28
−0.081	−0.070	−0.199	−0.363	−0.679	68.086	−.00311	29.394	31.2943	29
−1.403	−1.284	−1.127	−0.934	−1.143	62.855	−.00383	29.576	31.3555	30
+0.276	+0.359	+0.194	−0.006	+0.214	79.489	−.00354	30.365	32.0847	31
−0.367	−0.463	−0.341	−0.256	−0.357	73.167	−.00469	32.634	34.8137	32
+2.240	+2.466	+2.409	+2.351	+2.714	−23.764	−.000266	32.278	35.6678	33
−1.153	−1.391	−1.341	−1.399	−1.000	86.102	−.00192	36.052	36.9718	34
−1.617	−1.667	−1.663	−1.470	−1.214	288.413	−.0000982	39.242	40.0023	35
+0.276	+0.251	+0.409	+0.351	+0.214	71.721	−.00555	41.959	42.5391	36
−0.617	−0.499	−0.341	−0.684	−0.357	73.411	−.00366	43.919	45.2487	37
−1.117	−1.427	−0.949	−1.041	−1.214	71.835	−.00517	45.143	46.4531	38
−2.439	−2.427	−2.163	−1.756	−2.464	50.960	−.00209	44.911	46.5212	39
+3.954	+4.144	+3.194	+3.994	+3.464	14.529	+.000215	46.616	48.8655	40
+0.490	+0.180	+0.301	−0.184	−0.179	67.079	−.00315	61.165	65.3350	41

In chronometer room.

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APPENDIX B.

[Report of Commander Allan D. Brown.]

U. S. NAVAL OBSERVATORY,
Washington, September 26, 1887.

SIR: The work of the division of verification of instruments has been carried on under my general supervision by Lieutenant Winterhalter, until April 1, and by Ensign Clements since that date.

CLASS A.—SEXTANTS AND OCTANTS.

There have been received for examination 147 sextants; of these, 42 were new instruments recently purchased by the Bureau; 38 were the old ones referred to in the last report as having been examined, and since repaired by R. Merrill's Sons, of New York; and 67 were old ones to be inspected as to their fitness for repairs.

There have been examined 4 (on hand at the date of the last report) by Lieutenant Winterhalter; 8 new and 38 repaired ones mainly by Ensign Clements; and 67 old ones.

There have been sent to the navy-yard at New York, for issue, 4 new and 23 repaired ones; to be repaired, 54; condemned, 28.

CLASS B.—THERMOMETERS.

There have been examined three Peabody metallic thermometers; and also (at the request of the supervising surgeon-general of the Marine-Hospital Service) 130 clinical thermometers belonging to that service.

The Peabody thermometers were compared with the standards in daily use with results that could hardly be said to be favorable to them as instruments of precision.

The clinical thermometers were compared with the Fahrenheit and Centigrade standards of the Observatory, made by H. J. Green, of New York. In preparation for this work, a testing case was constructed upon the general plan of the temperature room used for testing chronometers as outlined in the last report. In this case (which is heated by means of water circulating through a pipe in a small gas stove of the American Meter Company's pattern), was placed a glass vessel containing water; this became gradually and uniformly heated, so far at least as could be determined by the standard thermometers, which read to the tenth of a degree. The standards were equally immersed at opposite extremities of the vessel, and the bulbs of the clinicals were suspended at the same depth. Each of the 130 instruments (save 1 broken and 3 that were defective) was compared at every two degrees, making about 1,000 readings in all. After examination they were returned to the Supervising Surgeon-General, with a certificate attached to each one.

This examination showed most conclusively the necessity that exists for the careful inspection of such instruments. Seven were found to be entirely unreliable; 58 were found to be unreliable at some point short of their full graduation, and but 61, or less than 50 per cent. of those examined, were found to be correct throughout their whole range.

CLASS C.—SPY-GLASSES.

One spy-glass by Elliott Brothers and three by Negretti and Zambra were examined early in the year by Lieutenant Winterhalter. As a

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result of this examination, a memorandum concerning the construction of such glasses was sent to the Bureau, and forwarded to the manufacturers for their guidance. Twenty-five have recently been received from Elliott Brothers, and have been examined; they were found to possess an excellent optical performance, but there were some points about the mechanical construction that could have been improved. As a whole, they are unquestionably superior to those that have lately been issued to the service.

CLASS D.—STATION POINTERS.

No instruments of this class have been examined.

CLASS E.—CLINOMETERS.

Four Evelyn's patent ship-clinometers, made mainly in accordance with the drawings and specifications mentioned in the last report, have been examined and found suitable for issue.

CLASS F.—BAROMETERS.

One holosteric barometer by Keuffel and Esser was examined early in the year by Lieutenant Winterhalter, and an exhaustive report thereon made to the Bureau.

CLASS G.—BINOCULARS.

Two binoculars by Chevallier and 2 by Hurlimann (the property of the Light-House Board) were examined by Lieutenant Winterhalter, and a memorandum concerning them sent to the Bureau.

The total number of instruments examined is as follows:

Class A. Sextants	117
Class B. Thermometers	133
Class C. Spy-glasses	29
Class D. Station Pointers	0
Class E. Clinometers	4
Class F. Barometers	1
Class G. Binoculars	4
Total	288

There remain on hand to be examined: Class A, sextants, 34.

Very respectfully,

ALLAN D. BROWN,
Commander, U. S. Navy, Assistant Superintendent.

The SUPERINTENDENT.

APPENDIX C.

[Report of Prof. William Harkness, of the Transit of Venus Commission.]

U. S. NAVAL OBSERVATORY,
Washington, September 28, 1887.

SIR: I have the honor to submit the following report of the work done during the past year, under my supervision, for the Transit of Venus Commission:

The assistants employed at the beginning of the year were Messrs. A. S. Flint and Herbert C. Wilson. Mr. H. P. Tuttle was engaged on

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January 5, 1887, and Mr. Wilson resigned on July 31, 1887, to become assistant director of the Carleton College Observatory, at Northfield, Minn. Messrs. Flint and Tuttle are still in the service of the Commission.

On April 27, of the present year, Mr. Joseph A. Rogers filed his report with the Commission. It covers 229 pages of manuscript, and embraces a complete account not only of his official photographic work in connection with the total solar eclipse of July 29, 1878, and the transits of Mercury and Venus, but also of many experiments carried out at his own private expense. Both from a theoretical and practical point of view he has investigated the conditions necessary for the successful production of pyroxyline suitable for astronomical photography, and although difficulties still remain, much that was heretofore obscure has now been made clear. It is believed that this investigation will have an important bearing on future work, for in all cases not demanding the most extreme sensitiveness collodion is certainly superior to gelatine.

The work done by Messrs. Flint, Wilson, Tuttle, and myself may be summarized as follows:

The scale-values of the bubble tubes of the engineer's levels, and also those of the latitude and striding levels belonging to the meridian instruments, and the revolution values of the screws of the double-image micrometers belonging to the equatorial telescopes have been submitted to a final revision and discussion. The reduction of the latitudes of all the stations, and the embodiment of the observations in tables for the printer, have been completed. The reduction and tabulation of the time-observations have also been completed, with the exception of four nights' work at Wellington, which is required for determining the instants of certain occultations; the tables of chronometer corrections and comparisons have been made out, and the chronometric longitudes measured in 1874–'75 have been recomputed. The double-image micrometer measurements of intervals between Venus and the sun's limb, widths of cusps, and diameters of Venus, both in 1874 and 1882, have all been reduced and tabulated; and, finally, the stars whose occultations were observed in 1882 have been identified.

The observations to determine the azimuths and levels of the axes of the photo-heliographs, and the intervals between the objectives and reticule-plates of these instruments, have been reduced and tabulated for all the stations except the Lick Observatory, from which the necessary data have not yet been received. The reduction and discussion of the experiments made in 1883–'85 to determine the radii of curvature of the heliostat mirrors, has recently been resumed, and is now nearly completed. Speaking generally, it shows that when exposed to the sun's rays the Lick mirror alone remained sensibly unchanged, while all the others became more concave—the increase of their versed sines on a chord of 5 inches being about the one-hundred-thousandth part of an inch for the Commission's mirrors, and four times that amount for the Princeton mirror.

As soon as the reduction of the observations for time and geographical position was practically completed the photographs were again taken up, and the work accomplished upon them since the beginning of the present year is as follows:

(1) *Quantities depending upon the tabular positions of the sun and Venus.*—The geocentric right ascensions and declinations of the sun and Venus have been computed by a special process for each twentieth minute

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of Greenwich sidereal time, from $18^h\ 40^m$ to $1^h\ 20^m$, and from them the geocentric position angles, and distances of Venus, relatively to the sun's center, have been computed and tabulated for every minute of Greenwich sidereal time, from $19^h\ 00^m$ to $1^h\ 00^m$. From the same data the parallactic elements P, P′, R, R′, θ, and θ', the quantities Δs and Δp, and the numbers whose sums will form the coefficients of the unknown quantities in the final normal equations derived from the photographs, have also been computed for each station for every twentieth minute of the time during which photographs were actually made; and the latter quantities have been interpolated to every fifth minute of time for seven of the stations. Further, the altitude, azimuth, and parallactic angle of the sun at each station have been computed for every twentieth minute of the time during which photographs were made; and the angle subtended upon the reticule-plate between the plumb line and the minor axis of the image of the sun, together with the differential coefficients of that angle, have also been computed for every twentieth minute for all the stations where needed, except the Lick Observatory.

(2) *Quantities depending upon the photographs.*—The rectangular co-ordinates of the center of Venus and the center of the plate relatively to the sun's center were long since computed from the plate measures for all the photographs except those taken in New Haven. During the present year these co-ordinates have been computed for the New Haven station, and have been tabulated for all the stations. The further reduction of these co-ordinates has been proceeded with, and at the present date the distances in scale divisions between the centers of the images of the sun and Venus, and the angles subtended at the center of the sun's image between the plate-holder plumb-line and Venus, have been computed for all the plates. The position angles and distances of Venus relatively to the sun's center, upon which the absolute terms of the observation equations for finding the solar parallax will depend, have not yet been obtained; but the coefficients of the unknown quantities in these equations have been interpolated for all the photographs taken at Washington, Cedar Keys, San Antonio, Cerro Roblero, and Wellington.

From the foregoing statement it will be apparent that the reduction of the United States transit of Venus observations is fast drawing to a close, and it is believed that if no unforeseen obstacle arises the value of the solar parallax deducible from them will be obtained about the end of the present calendar year.

Since the date of my last report the observations on terrestrial magnetism, made in 1874, at Peking, Nagasaki, Kerguelen island, Queenstown, and Chatham island have been reduced, and the tidal observations made at Kerguelen island have been partially reduced.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics, U. S. Navy,
Of Executive Committee of Transit of Venus Commission.

Capt. R. L. PHYTHIAN, U. S. Navy,
Superintendent Naval Observatory,
President of Transit of Venus Commission.

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REPORT

OF

THE SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR

THE YEAR ENDING JUNE 30, 1888.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1888.

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REPORT

OF

SUPERINTENDENT OF NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, October 15, 1888.

SIR: I have the honor to submit the annual report of the Naval Observatory, in compliance with the Bureau's order dated October 1, 1888, (No. 2600).

Changes in the personnel have occurred since the date of the last report, October 5, 1887, as follows: Detached—Ensign W. G. Richardson, in October, 1887; Lieut. W. H. Allen, October 17, 1887; Lieut. H. W. Schaefer, December 31, 1887; Ensign V. O. Chase, February 16, 1888; and Lieut. S. C. Paine, April 23, 1888. Reported for duty—Ensign C. C. Marsh, December 19, 1887; Ensign H. S. Chase, January 14, 1888.

DISTRIBUTION OF WORK.

The work of the Observatory is at present distributed as follows:

Assistant Superintendent—Commander A. D. Brown.

Chronometers and time service—Ensign A. N. Mayer.

East transit instrument—Lieuts. L. C. Heilner and B. W. Hodges.

Inspection of instruments—Ensign A. B. Clements.

Compass houses—Lieut. William P. Elliott and Ensign C. C. Marsh.

Great equatorial—Prof. Asaph Hall and Ensign H. S. Chase.

Transit circle—Prof. J. R. Eastman, Assistant Astronomers A. N. Skinner, William C. Winlock, and H. M.Paul, and Computer William M. Brown.

The 9.6-inch equatorial—Prof. Edgar Frisby.

Photography.—Lieut. A. G. Winterhalter.

Instrument-maker.—William F. Gardner.

Clerk.—Thomas Harrison.

The meteorological observations are made by the watchmen, Dennis Horigan, Nicholas Cahill, and William Henderson, under the supervision of the assistant superintendent.

Prof. William Harkness is also attached to the Observatory for special duty as the member of the Transit-of-Venus Commission having direct charge of the reductions and computations of the observations of 1874 and 1882.

THE GREAT EQUATORIAL.

(Professor Hall, in charge.)

This instrument is in good order and is in continual use. The flint lens was repolished by Alvan Clark & Sons in May, 1876, when the figure was a little improved. The objective retains its figure and polish

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well. Very little discoloration has appeared in the lenses, and their defining power is as good as ever. By comparison with several other objectives which Professor Hall has had an opportunity of making during recent years, he finds that our glass is an excellent one. The arrangements for setting the instrument on an object are very simple, but in practice they work well. An improvement might very well be made in the illumination of this instrument by the introduction of electric lights.

The micrometrical measurements have been those of the satellites of Saturn and Mars, and of the regular list of double stars. Some conjunctions of the inner satellites of Saturn with the minor axis of the ring were also observed. The surface of Saturn was carefully observed during the last opposition, and some drawings of this planet are nearly completed. Particular attention was given to the shadows cast by the ball of Saturn on his ring, to the markings on the ball, and to the divisions of the ring. Special attention was given to the surface of Mars during and after the last opposition, in the hope of seeing the "canals" described by several observers, but these singular objects could not be made out.

The reduction and discussion of the observations made with this instrument are now well advanced. Lieut. William H. Allen, who rendered very efficient service in this part of the work, was detached last October. Ensign H. S. Chase was assigned as an assistant on this instrument in March, 1888, and has been employed in copying and arranging for printing the notes on Saturn, and in reducing the measurements of the ring and ball of this planet. These observations are ready for publication. Mr. Chase has also continued computations on the theory of Hyperion, the faint satellite of Saturn, which has a curious motion developed by the observations made with this instrument since 1875. The theory of this motion is now so far advanced that we hope to discuss all our observations of Hyperion, and to represent them within the limits of the probable errors for such a faint object.

The general working of the dome and shutters, and the engine for moving the dome, are in charge of Mr. George Anderson, who has performed his duties in a satisfactory manner.

THE TRANSIT CIRCLE.

(Professor Eastman, in charge.)

This instrument was employed in the observation of stars of the American Ephemeris, the sun, moon, and planets, and until April, 1888, of such miscellaneous stars as were necessary to complete the data for the star catalogue. After April 4, 1888, the instrument was dismounted and cleaned. When it was re-mounted in July, observations were begun upon the sun, moon, major and minor planets, and such stars as were necessary for clock and instrumental corrections.

From October 1, 1887, to date, the whole number of observations with the transit circle was 1,970. Of these, 69 were of the sun; 40 of the moon, and 107 of the major planets. At the request of the director of Columbia College Observatory, New York, clock signals were exchanged on six nights in August and September last, to determine the longitude of that observatory.

Early in April, 1888, it was decided to undertake the observation of the zone of stars between—14° and—18° declination for the German Astronomical Society. The preparation of the observing lists was begun

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in April, and it is expected that the observations will begin within a few weeks.

Since the last report the transit circle work for 1883 has been printed, and the work for 1884 is now in press. The computations for the work of 1885 are now more than half done; no work has been done on the computations for 1886. It is impossible to bring up properly the computing and copying now in arrears, or to attempt the work on the German zone with credit to this Observatory, without a greater force of experienced computers. An increase in this force has been recommended and urged by my predecessors for several years past. Two additional computers are asked for in the estimates for the next fiscal year, and it is earnestly hoped that they will be allowed.

THE 9.6-INCH EQUATORIAL.

(Professor Frisby, in charge.)

This instrument has been used for the identification of stars in the revision of Yarnall's Catalogue, and in observations of small planets, comets, and of occultations of stars by the moon. Three comets have been seen during the year, and thirty-five observations made, all of which, as far as reduced, have been published in the Astronomical Journal. Nine observations of occultations of stars by the moon and a few observations of minor planets have been made. Two evenings in each week have been set apart for the accommodation of visitors.

All the work of revision of Yarnall's Catalogue is substantially completed, and the main part of the printing done; the notes are nearly ready for the press, and it is believed that the whole work will soon be published.

CHRONOMETERS AND TIME SERVICE.

(Lieutenant Paine in charge until April 23; since then Ensign Mayer.)

Chronometers have been received, issued, cleaned, condemned, and purchased during the year as follows:

	Received from service.	Issued.	Cleaned.	Condemned.	Purchased.
Box chronometers	36	39	48	9	14
Hack chronometers	8	9	5	.....	.....

The following is the disposition of the chronometers belonging to the Navy:

	Issued.	On trial.	Under repairs.	Awaiting repairs.	Loaned.	Ready for issue.
Box chronometers	150	26	42	21	3	42
Hack chronometers	70	.....	2	133	3	5
Pocket chronometers	1	.....	.....	5	.....	1
Pocket-hack chronometers	2	.....	.....	4	.....	.....
Comparing watches	.....	.....	.....	4	.....	.....

Of those classed as issued, 25 box, 9 "hack," and 2 "pocket-hacks" are at the branch observatory at Mare Island.

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The temperature room was in use from the 1st of January to the 16th of March, for the trial of thirty box chronometers submitted to competition. At the same time there were placed on trial twenty-four box and one pocket instrument, belonging to the Navy which had recently been repaired and regulated. The trial was conducted in the same manner as was the preceding one, except that the hygrometric test was omitted. Of those submitted for competition, fourteen were recommended for purchase. The results of the trial will be found recorded in the accompanying appendixes A and B.

The alterations in the temperature room, to which allusion was made in the last report, have so increased its efficiency that it will in future be practicable to begin the trials at an earlier date.

The chronometers that are now being returned to the Observatory from ships going out of commission were issued with rate-curve sheets. Upon some of these sheets the records have been continued, but in most instances they are either incomplete or entirely neglected. As these records are not only important and interesting histories of the sea-performance of chronometers, but also valuable to makers when instruments are placed in their hands for repairs, it is desirable that they should be kept up with systematic regularity. It is therefore recommended that the attention of commanding and navigating officers be called to the importance of so keeping them.

The Observatory continues to send daily over the wires of the Western Union Telegraph Company the time-signal at noon of the seventy-fifth meridian. By it time-balls are dropped at Newport, R. I., Wood's Holl, New York, Philadelphia, Baltimore, Washington, Hampton Roads, Savannah, and New Orleans. The signal is also sent over the lines of a number of railroads, and their time-pieces are regulated by it.

On the Observatory clock line in this city there are 347 Gardner clocks, principally in Government buildings, which are automatically corrected by the daily noon signal.

EAST TRANSIT INSTRUMENT.

(Lieutenant Heilner, in charge.)

The condition of this instrument is good. All the clocks are performing well. Daily observations, when practicable, were made for the correction of the standard mean-time clock.

EXAMINATION OF INSTRUMENTS.

This division has been under the general supervision of the assistant superintendent, Commander Allan D. Brown, whose report is appended, marked C.

MAGNETIC INSTRUMENTS.

(Lieutenant Elliott, in charge.)

Observations of absolute declination have been made twice each day, the practice being to observe at 10 a. m. and 3 p. m. From these, appropriately grouped, the value of the photographed base lines of the declination magnetograms is deduced. The performance of the large declination magnet and theodolite is good, and the results are believed to be within a close limit of correctness.

An observation or experiment for the determination of the absolute horizontal intensity is made Tuesday of each week. About twenty vi-

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bration experiments, with inertia cylinder in place, have also been made for the verification of the value of K found at Kew observatory in 1879. The magnets used in these experiments and the instrument are in excellent condition. The forms are so arranged that the computation of results at the end of the year or series is only a few hours' work.

Three needles have been used in observations of inclination during the year, the practice being to use each needle once a week.

The performance of the declination and horizontal force magnetographs has been excellent. They were re-adjusted at the beginning of the year and scale values redetermined with the following results:

Declination.—One centimeter of ordinate = 11′.29 arc.

Horizontal force.—One centimeter of ordinate = .0008 c. g. s. units.

The vertical force magnetograph has been at no time in satisfactory adjustment. A serious chipping of the agate knife-edge was discovered, and a new agate has been ordered. It is hoped that when the new agate arrives this delicate instrument can be successfully adjusted.

The computation, tabulation, and general record of observations have been kept up, as far as compatible with the scheme of the work.

THE LIBRARY.

The library now contains over 12,000 volumes and 2,600 pamphlets. The accessions during the year have been 513—459 volumes and 54 pamphlets. Of these, 288 were received in exchange and 225 were purchased.

The want of a librarian has been greatly felt the past year; and the services of an indexer and copyist (for which estimates have been submitted) are very much needed.

THE CENTENNIAL EXPOSITION AT CINCINNATI.

The Observatory exhibit, a detailed report of which will be made at the close of the exposition, is a very creditable one. A marked feature of the exhibit is the time-ball dropped daily, by signal from the Observatory, from a staff on the main building. The apparatus for its manipulation was set up and adjusted by Mr. William F. Gardner, the inventor, to whom is due all the credit for its successful performance.

INTERNATIONAL ASTROPHOTOGRAPHIC CONGRESS.

As mentioned in the last report, Lieut. A. G. Winterhalter was detailed by the Department as the representative of the Observatory at the International Astrophotographic Congress, held at Paris in April, 1887. After the adjournment of the congress Lieutenant Winterhalter, by order of the Department, visited the principal observatories and other establishments of a scientific character in England, France, Germany, Austria, Holland and Italy. Since his return to the United States, in November last, he has been actively engaged in the preparation of his report, which is now nearly completed.

THE NEW NAVAL OBSERVATORY.

The contract for the erection of the nine buildings comprising the new Observatory, awarded to Messrs. P. H. McLaughlin & Co., of Washington, D. C., having been executed, the work upon them will be commenced at once.

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The amount already appropriated will be sufficient to make the partial payments called for in the contract until the end of the second session of the present Congress. It is not sufficient, however, to admit of contracts being made for the domes until further appropriations shall be made.

CONNECTION WITH WASHBURN OBSERVATORY.

By resolutions of the board of regents of the University of Wisconsin, transmitted to the Department through President T. C. Chamberlin, the free use of the Washburn Observatory during the removal of the Naval Observatory was tendered.

Co-ordination of work between the two observatories was invited by the same authorities and cordially accepted. Prof. Asaph Hall, the senior astronomer at this observatory, was, with the consent of the Department, appointed consulting director of the Washburn Observatory, which office he now holds, and Prof. S. J. Brown was detailed for duty there.

MISCELLANEOUS.

A record of the state of the "seeing" has been kept by the watchmen, from which it appears that on 174 nights it was cloudy, on 113 the seeing was poor, on 63 it was fair, on 12 it was good, and on but 2 very good.

The names of 1,764 visitors have been recorded during the year, and 1,499 permits for night visitors have been issued.

The report of Prof. William Harkness of the progress of work for the Transit-of-Venus Commission is herewith forwarded, marked Appendix D.

Appendix E is a letter from Lieutenant Winterhalter, preliminary to his report, to which allusion has been made.

I invite the attention of the Bureau to his recommendations that provision be made to enable this Observatory to do the work which will fall to its share in charting the sky by photographic processes. Plans and estimates will be submitted as soon as they can be prepared.

Very respectfully,

R. L. PHYTHIAN,
Captain, U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF NAVIGATION,
Navy Department.

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APPENDIX A.—*Record of competitive trial of chronometers, January, 1888–July, 1888.*

[In temperature room from January 4 to March 16; after that in chronometer room.]

Time	Jan. 4 to Jan. 11	Jan. 12 to Jan. 19	Jan. 20 to Jan. 27	Jan. 29 to Feb. 5	Feb. 6 to Feb. 13	Feb. 14 to Feb. 21	Feb. 22 to Feb. 29	Mar. 1 to Mar. 8	Mar. 9 to Mar. 16	Mar. 16 to Mar. 23	Mar. 23 to Mar. 30	Mar. 30 to Apr. 6	Apr. 6 to Apr. 13	Apr. 13 to Apr. 20	Apr. 20 to Apr. 27
Temperature, Fahrenheit	44°.87	55° 02	70°.04	85°.01	90°.01	85°.02	69°.93	54°.95	44°.90	51°.93	52°.75	65°.85	65°.53	63°.08	61°.75
Relative humidity, per cent	69.5	68.5	70.7	69.5	70.0	70.0	68.6	67.6	67.7	60.0	64.6	63.5	58.0	58.0	52.0

	Chronometer maker.	*No.*	*Description of balance, given by maker.*														
				s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	T. S. & J. D. Negus	1775	Ordinary balance, with Negus correction.	−2.636	−2.380	−2.061	−2.487	−2.567	−2.194	−1.994	−2.051	−1.997	−1.719	−1.704	−1.279	−1.333	−1.337	−1.256
2	....do	1748	Flat-rim balance	+0.543	−0.023	−0.204	−0.094	−0.067	−0.301	−0.494	−0.409	−0.140	−0.183	−0.311	−0.529	−0.726	−0.659	−0.613
3	....do	1767	Ordinary balance, with Negus correction.	−1.636	−1.451	−1.633	−1.809	−1.889	−1.730	−1.494	−1.837	−1.783	−1.469	−1.490	−0.921	−0.797	−0.694	−0.577
4	Wm. Bond & Son	529	Hartnup balance	−0.171	+0.441	+0.439	−0.344	−0.781	−0.551	+0.077	−0.123	−0.461	−0.040	−0.061	+0.257	+0.167	+0.270	+0.280
5	T. S. & J. D. Negus	1723	Ordinary balance, with Negus correction.	+0.864	+0.513	+0.939	+0.763	+0.754	+0.770	+0.720	+0.484	+1.074	+1.103	+0.974	+1.079	+1.024	+1.163	+1.459
6	....do	1768	do	−1.814	−1.130	−0.663	−1.701	−2.031	−1.659	−0.816	−0.801	−1.140	−0.683	−0.704	0.493	−0.440	−0.409	−0.256
7	Wm. Bond & Son	520	Plain balance	−2.529	−1.273	−0.919	−1.880	−2.353	−2.230	−1.244	−1.587	−2.533	−1.254	−1.311	−0.814	−1.011	−0.944	−0.863
8	T. S. & J. D. Negus	1773	Ordinary balance, with Negus correction.	−1.064	−1.201	−0.990	−0.880	−0.746	−0.409	−0.280	−0.373	−0.497	−0.290	−0.347	+0.293	+0.310	+0.234	+0.280
9	H. H. Heinrich	811	Ordinary balance, with Heinrich's auxiliary.	−0.064	+0.906	+0.653	+0.084	+0.076	−0.087	+0.291	+0.020	−0.140	+0.317	+0.474	+0.864	+0.917	+0.734	+0.744
10	T. S. & J. D. Negus	1721	Ordinary balance	−2.064	−1.059	−0.669	−1.737	−2.389	−1.944	−1.244	−1.730	−2.211	−1.897	−1.954	−1.136	−1.154	−1.123	−1.041
11	....do	1762	do	−3.029	−1.737	−0.847	−1.666	−2.424	−1.766	−1.030	−1.944	−2.961	−1.933	−1.883	−1.064	−1.119	−1.016	−0.899
12	Wm. Bond & Son	514	Hartnup balance	−1.564	−1.987	−2.419	−3.416	−3.103	−2.587	−2.030	−1.801	−2.176	−1.897	−2.061	−1.743	−1.654	−1.337	−1.041
13	John Bliss & Co	2809	Ordinary balance	−1.564	−0.594	+0.260	−0.844	−1.317	−0.873	+0.326	−0.587	−2.319	−1.183	−0.883	+0.221	+0.346	+0.413	+0.244
14	T. S. & J. D. Negus	1739	do	−3.421	−1.666	−0.240	−0.451	−0.889	−0.659	−0.316	−1.873	−3.819	−2.326	−2.097	−0.529	−0.619	−0.266	−0.399
15	H. H. Heinrich	3458	Ordinary bal., with Heinrich's auxiliary palladium spring.	−1.421	−1.559	−1.276	−0.309	−0.281	−0.909	−1.101	−2.159	−1.997	−2.004	−1.847	−1.564	−1.797	−1.587	−1.541
16	Wm. Bond & Son	501	Plain balance	−1.564	−0.273	+1.010	−0.094	−0.139	+0.127	+0.970	+0.520	−0.854	+0.496	+0.439	+1.614	+1.310	+1.234	+1.494
17	T. S. & J. D. Negus	1765	Ordinary balance, with Negus correction.	−2.921	−1.951	−1.847	−2.987	−3.460	−2.909	−1.959	−1.516	−2.604	−1.826	−1.883	−0.779	−0.761	−0.944	−0.934
18	John Bliss & Co	2818	Bliss auxiliary balance	−1.493	−0.380	+0.724	+0.013	−0.389	−0.337	+0.684	+0.627	−0.533	+0.210	+0.153	+0.579	+0.810	+1.449	+1.566
19	Wm. Bond & Son	482	Plain balance	−1.029	−0.059	+0.403	−0.916	−1.924	−1.516	−0.637	−0.730	−0.783	−0.754	−0.454	−0.243	−0.119	−0.194	−0.256
20	John Bliss & Co	2810	Bliss auxiliary balance	−0.243	+0.763	+0.546	−0.023	+0.433	+0.413	+0.756	+1.341	+0.539	+1.139	+0.974	+1.186	+1.024	+1.413	+1.387
21	T. S. & J. D. Negus	1774	Ordinary balance, with Negus correction.	−2.064	−1.987	−1.740	−1.630	−1.603	−1.087	−1.030	−0.801	−0.247	−0.326	−0.669	−0.707	−0.440	−0.230	−0.113
22	....do	1776	do	−1.386	−1.630	−1.097	−1.451	−1.710	−1.087	−0.423	−0.480	−0.283	−0.290	−0.419	−0.171	−0.011	+0.234	+0.280
23	John Bliss & Co	2851	Ordinary balance	−2.243	−0.130	+1.296	+0.727	+0.111	+0.841	+1.613	+0.699	−1.104	+0.424	+0.403	+2.043	+2.060	+2.199	+2.173

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APPENDIX A.—*Record of competitive trial of chronometers, January, 1888–July, 1888*—Continued.

			Jan. 4 to Jan. 11	Jan. 12 to Jan. 19	Jan. 20 to Jan. 27	Jan. 29 to Feb. 5	Feb. 6 to Feb. 13	Feb. 14 to Feb. 21	Feb. 22 to Feb. 29	Mar. 1 to Mar. 8	Mar. 9 to Mar. 16	Mar. 16 to Mar. 23	Mar. 23 to Mar. 30	Mar. 30 to Apr. 6	Apr. 6 to Apr. 13	Apr. 13 to Apr. 20	Apr. 20 to Apr. 27
Time																	
Temperature, Fahrenheit			44°.87	55°.02	70°.04	85°.01	90°.01	85°.02	69°.93	54°.95	44°.90	51°.93	52°.75	65°.85	65°.53	63°.08	61°.75
Relative humidity, per cent			69.5	68.5	70.7	69.5	70.0	70.0	68.6	67.6	67.7	60.0	64.6	63.5	58.0	58.0	52.0
	Chronometer maker—Continued.	*No.*	*Description of balance, given by maker*—Continued.														
				s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
24	John Bliss & Co	2852	Ordinary balance	−3.529	−1.916	−0.347	−0.594	−0.817	−0.016	+0.256	−0.909	−2.211	−1.040	−0.740	+0.829	+0.810	+0.806	+0.744
25	Wm. Bond & Son	480	Plain balance	+0.364	+1.013	+0.046	−2.094	−2.996	−2.301	−0.709	−0.266	−0.604	−0.147	−0.383	−0.100	−0.069	+0.127	+0.209
26	John Bliss & Co	2813	Bliss auxiliary balance	+0.007	+1.513	+1.831	+1.656	+3.647	+1.663	+2.756	+1.806	+0.753	+1.531	+1.367	+2.007	+1.953	+1.984	+2.030
27	....do	2853	Ordinary balance	−2.100	−0.773	+0.724	+1.013	+0.647	+1.306	+1.756	+0.984	+0.039	+1.281	+1.260	+2.436	+2.560	+2.449	+2.601
28	....do	2792	Auxiliary balance	+1.471	+1.906	+1.010	+1.584	+1.397	+1.484	+0.863	+2.020	+1.610	+2.246	+2.296	+1.543	+1.381	+1.699	+1.887
29	....do	2827	Ordinary balance	−0.850	+0.656	+2.296	+1.477	+1.326	+2.020	+2.970	+2.127	+0.717	+2.674	+2.617	+4.221	+4.167	+4.199	+4.387
30	....do	2829	.....do	−2.171	−1.059	+0.939	+1.299	+1.540	+2.127	+2.827	+1.556	−0.176	+1.174	+1.224	+1.900	+2.703	+3.199	+3.137

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APPENDIX A.—*Record of competitive trial of chronometers, January, 1888–July, 1888*—Continue

[In temperature room from January 4 to March 16; after that in chronometer room.]

Time	Apr. 27 to May 4	May 4 to May 11	May 11 to May 18	May 18 to May 25	May 25 to June 1	June 1 to June 8	June 8 to Ju'e 15	Ju'e 15 to Ju'e 22	Ju'e 22 to Ju'e 29	Ju'e 29 to July 6	Temperature of compensation.	Temperature constant.	First trial number.	Final trial number.
Temperature, Fahrenheit	71°.15	73°.17	71°.04	67°.66	75°.18	73°.15	75°.53	82°.09	83°.56	74°.95				
Relative humidity, per cent	58.0	62.7	60.5	62.8	70.1	66.6	68.0	66.7	66.8	62.0				

	Chronometer maker.	No.	Description of balance, given by maker.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	°	s.	s.	s.
1	T. S. & J. D. Negus	1775	Ordinary balance, with Negus correction.	−1.041	−1.021	−1.083	−0.837	−0.890	−0.921	−0.847	−0.816	−0.919	−0.831	68.129	−0.00111	4.8059	6.3188
2	do	1748	Flat-rim balance	−0.684	−0.271	−0.369	−0.337	+0.039	+0.186	+0.081	+0.149	+0.010	+0.133	69.500	+0.000633	3.8825	6.6381
3	do	1767	Ordinary balance, with Negus correction.	−0.434	−0.343	−0.440	−0.230	−0.354	−0.386	−0.276	−0.566	−0.597	−0.403	66.733	−0.000643	2.4891	6.6507
4	Wm. Bond & Son	529	Hartnup balance	+0.316	+0.300	+0.167	+0.449	+0.396	+0.436	+0.439	+0.184	+0.010	+0.383	64.347	−0.00179	9.2838	10.3242
5	T. S. & J. D. Negus	1723	Ordinary balance, with Negus correction.	+1.030	+0.907	+0.703	+0.949	+0.896	+0.686	+0.760	+0.970	+0.974	+0.776	75.102	−0.000875	*10.6658	13.2902
6	do	1768	do	−0.291	−0.343	−0.476	−0.230	−0.390	−0.243	−0.169	−0.744	−0.740	−0.046	65.381	−0.00258	12.3659	13.4268
7	Wm. Bond & Son	520	Plain balance	−0.684	−0.521	−0.869	−0.337	−0.997	−1.350	−1.383	−1.601	−1.883	−1.331	66.475	−0.00293	13.4033	16.4309
8	T. S. & J. D. Negus	1773	Ordinary balance, with Negus correction.	+0.709	+0.801	+0.703	+0.734	+0.824	+0.757	+0.939	+0.970	+0.867	+0.990	76.662	−0.000356	12.3121	16.6802
9	H. H. Heinrich	811	Ordinary balance, with Heinrich's auxiliary.	+1.173	+1.407	+1.274	+1.091	+1.074	+1.257	+1.189	+1.149	+1.010	+0.740	62.780	−0.00107	11.6065	16.7141
10	T. S. & J. D. Negus	1721	Ordinary balance	−0.791	−0.629	−0.761	−0.480	−0.640	−0.671	−0.704	−1.101	−1.276	−0.724	67.470	−0.00294	16.4786	18.2742
11	do	1762	do	−1.041	−0.807	−0.940	−0.730	−0.747	−0.707	−0.669	−1.066	−1.204	−0.724	70.553	−0.00373	17.4764	19.2989
12	Wm. Bond & Son	514	Hartnup balance	−1.256	−1.020	−1.083	−0.944	−0.640	−0.779	−0.454	−0.744	−0.811	−0.367	51.426	−0.000993	12.8261	23.8485
13	John Bliss & Co	2809	Ordinary balance	+0.351	+0.407	+0.239	+0.377	+0.039	+0.293	+0.189	−0.351	−0.454	+0.204	69.012	−0.00452	23.8026	24.4915
14	T. S. & J. D. Negus	1739	do	−0.041	+0.014	−0.190	−0.159	+0.074	+0.114	−0.240	−0.244	−0.347	−0.367	75.150	−0.00393	22.8828	25.9804
15	H. H. Heinrich	3458	Ordinary bal., with Heinrich's auxiliary palladium spring.	−1.863	−1.557	−1.083	−1.123	−1.461	−1.636	−1.490	−1.851	−2.276	−2.117	171.902	−0.000504	16.7277	26.0913
16	Wm. Bond & Son	501	Plain balance	+1.637	+1.729	+1.596	+1.663	+1.289	+1.543	+1.331	+0.791	+1.010	+1.490	69.564	−0.00409	24.9137	26.1681
17	T. S. & J. D. Negus	1765	Ordinary balance, with Negus correction.	−0.756	−0.843	−1.011	−0.587	−1.211	−1.171	−1.204	−1.709	−1.919	−1.296	59.586	−0.00195	15.2523	27.3627
18	John Bliss & Co	2818	Bliss auxiliary balance	+1.137	+1.336	+1.060	+1.306	+1.003	+1.114	+1.046	+0.720	+0.581	+1.526	68.523	−0.00321	21.7527	27.9031
19	Wm. Bond & Son	482	Plain balance	−0.184	−0.093	−0.369	−0.194	−0.211	−0.100	−0.133	−0.494	−0.069	−0.224	65.520	−0.00306	27.8888	29.1884
20	John Bliss & Co	2810	Bliss auxiliary balance	+0.851	+0.764	+0.810	+1.091	+0.646	+0.579	+0.689	+0.756	+0.831	+0.740	46.863	−0.000122	26.0661	29.3785
21	T. S. & J. D. Negus	1774	Ordinary balance, with Negus correction.	+0.030	+0.229	+0.203	+0.377	+0.324	+0.436	+0.546	+0.506	+0.474	+0.776	55.000	+0.00004	25.0864	29.4128
22	do	1776	do	+0.173	+0.121	+0.167	+0.413	+0.289	+0.364	+0.439	+0.327	+0.260	+0.669	68.004	−0.00178	27.3121	29.5322
23	John Bliss & Co	2851	Ordinary balance	+2.816	+3.014	+2.953	+3.056	+3.360	+3.364	+3.474	+3.113	+2.831	+3.526	72.038	−0.00409	29.1727	34.0568

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APPENDIX A.—*Record of competitive trial of chronometers, January,* 1888–*July,* 1888—Continued.

			Apr. 27 to May 4	May 4 to May 11	May 11 to May 18	May 18 to May 25	May 25 to June 1	June 1 to June 8	June 8 to Ju'e 15	Ju'e 15 to Ju'e 22	Ju'e 22 to Ju'e 29	Ju'e 29 to July 6	Temperature of compensation.	Temperature constant.	First trial number.	Final trial number.
Time																
Temperature, Fahrenheit			71°.15	73°.17	71°.04	67°.66	75°.18	73°.15	75°.53	82°.09	83°.56	74°.95				
Relative humidity, per cent			58.0	62.7	60.5	62.8	70.1	66.6	68.0	66.7	66.8	62.0				
	Chronometer maker—Continued.	*No.*	*Description of balance given by maker*—Continued.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	°	s.	s.	s.
24	John Bliss & Co	2852	Ordinary balance	+1.530	+1.943	+1.953	+2.020	+2.253	+2.364	+2.439	+2.424	+2.296	+2.526	75.103	−0.00362	36.8166	41.1015
25	Wm. Bond & Son	480	Plain balance	−0.149	−0.164	−0.190	+0.270	−0.247	−0.136	−0.276	−0.887	−1.133	−0.189	53.004	−0.00247	35.4933	43.7302
26	John Bliss & Co	2813	Bliss auxiliary balance	+2.173	+2.229	+2.167	+2.270	+2.181	+2.329	+2.331	+2.041	+1.939	+2.210	70.000	−0.00282	46.3169	47.2194
27	do	2853	Ordinary balance	+3.101	+3.336	+3.310	+3.556	+3.896	+3.864	+4.081	+4.113	+4.046	+4.347	76.543	−0.00269	55.0717	59.3981
28	do	2792	Auxiliary balance	+1.030	+1.121	+1.096	+1.199	+1.503	+1.293	+1.510	+1.827	+1.617	+1.133	71.980	+0.00362	57.5067	60.5692
29	do	2827	Ordinary balance	+5.101	+5.443	+5.060	+5.413	+5.898	+5.936	+6.153	+5.899	+5.939	+6.204	71.259	−0.00473	55.3057	69.2186
30	do	2829	do	+3.397	+3.550	+3.667	+3.091	+3.860	+4.114	+4.189	+3.970	+4.081	+4.383	76.087	−0.00401	117.3628	135.4253

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APPENDIX B.—*Record of trial of repaired chronometers, January, 1888–July, 1888.*

[*In* temperature room from January 4 to March 16; after that, in chronometer room. Explanation of abbreviations in first column: Bo., repaired by William Bond & Son; Bl., repaired by John Bliss & Co.; N., repaired by T. S. & J. D. Negus.]

	Time		Jan. 4 to Jan. 11.	Jan. 12 to Jan. 19.	Jan. 20 to Jan. 27.	Jan. 29 to Feb. 5.	Feb. 6 to Feb. 13.	Feb. 14 to Feb. 21.	Feb. 22 to Feb. 29.	Mar. 1 to Mar. 8.	Mar. 9 to Mar. 16.	Mar. 16 to Mar. 23.	Mar. 23 to Mar. 30.	Mar. 30 to Apr. 6.	Apr. 6 to Apr. 13.	Apr. 13 to Apr. 20.	Apr. 20 to Apr. 27.
	Temperature, Fahrenheit ..		44°.87	55°.02	70°.04	85°.01	90°.01	85°.02	69°.93	54°.95	44°.90	51°.93	52°.75	65°.85	65°.53	63°.08	61°.75
	Relative humidity, per cent.		69.5	68.5	70.7	70.0	69.5	70.0	68.6	67.6	67.7	60.0	64.6	63.5	58.0	58.0	52.0
	Chronometer maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
N.	T. S. & J. D Negus..	1283	−2.493	−1.594	−0.990	−1.630	−2.210	−1.694	−0.851	−1.480	−2.283	−1.576	−1.633	−1.029	−1.011	−1.016	−1.041
N.	...do.....	1343	−3.529	−2.237	−1.383	−2.059	−2.496	−2.159	−1.601	−2.373	−3.354	−2.255	−2.169	−1.171	−1.119	−0.980	−1.006
Bl.	John Hutton	318	−1.207	−0.273	+0.010	−0.773	−1.031	−0.730	−0.137	−0.730	−1.569	−0.790	−0.847	+0.293	+0.274	+0.234	+0.316
N.	T. S. & J. D. Negus	1345	−1.993	−0.273	+0.689	+0.263	−0.103	+0.199	+0.541	−0.373	−1.783	−0.361	−0.383	+0.971	+0.953	+0.949	+0.816
N.	....do.....	1308	−4.671	−3.130	−2.669	−3.166	−3.674	−3.123	−2.494	−3.409	−5.104	−3.861	−3.883	−2.600	−2.619	−2.694	−2.756
N.	.. do.....	1273	−2.064	−1.416	−1.061	−2.201	−2.674	−2.266	−1.066	−1.230	−2.176	−1.361	−1.526	−0.814	−0.654	−0.587	−0.506
N.	....do.....	863	−1.671	−0.737	−0.526	−0.987	−1.531	−1.159	−0.137	−0.659	−1.676	−0.826	−0.883	+0.293	+0.274	+0.591	+0.566
N.	...do.....	1245	−1.421	+0.049	+0.760	+0.013	−0.174	+0.091	+0.827	+0.199	−1.461	−0.504	−0.419	+1.007	+0.846	+0.663	+0.566
N.	.. do	1298	−2.314	−0.880	−0.204	−1.023	−1.639	−1.301	−0.587	−0.873	−1.926	−0.469	−1.097	−0.243	−0.190	−0.194	−0.220
N.	.. do.....	1220	−2.207	−0.880	−0.169	−0.987	−1.353	−0.980	−0.244	−1.266	−2.533	−1.290	−1.204	−0.136	−0.047	+0.020	+0.101
N.	...do.....	1259	−2.421	−1.523	−1.061	−2.166	−2.674	−2.337	−1.351	−1.873	−3.283	−2.147	−1.811	−1.029	−1.047	−0.944	−1.077
Bl.	John Hutton	352	−2.529	−1.594	−1.097	−2.237	−3.067	−2.480	−1.316	−1.587	−2.961	−2.111	−1.919	−0.957	−0.976	−1.194	−1.149
Bl.	do	225	−2.386	−0.594	+0.796	+0.549	+0.039	+0.341	+0.541	−0.587	−2.533	−0.683	−0.669	+0.936	+0.846	+0.841	+0.709
N.	T. S. & J. D. Negus..	1115	−1.314	−0.380	−0.133	−1.451	−2.174	−1.623	−0.530	−0.623	−1.926	−0.897	−0.847	+0.114	+0.060	+0.161	+0.209
Bl.	John Bliss & Co	2484	+0.329	+1.691	+2.689	+1.941	+1.040	+1.591	+2.041	+1.234	+0.074	+1.389	+1.581	+2.471	+2.203	+2.341	+2.351
N.	T. S. & J. D. Negus..	1448	−1.814	−0.237	+0.010	−1.523	−2.353	−1.659	−0.494	−0.337	−1.461	−0.433	−0.347	+0.079	+0.024	+0.127	+0.101
N.	.. do.....	740	−3.171	−2.130	−1.919	−3.416	−3.924	−3.551	−2.030	−2.016	−3.176	−2.254	−2.419	−1.636	−1.797	−1.694	−1.684
N.	...do.....	1319	−1.064	+0.227	+0.546	−0.594	−1.460	−0.980	−0.137	−0.551	−1.497	−0.290	−0.490	+0.471	+0.203	+0.199	+0.244
Bo.	John Munroe	275	−2.171	−1.951	−1.240	−1.380	−1.817	−1.337	−1.601	−2.551	−4.104	−2.826	−2.990	−1.600	−1.619	−1.730	−1.720
Bl.	John Bliss & Co.....	2768	−4.207	−2.666	−1.633	−1.666	−0.960	−0.766	−1.137	−2.051	−3.497	−2.040	−1.883	−0.707	−0.833	−1.051	−1.077
Bo.	Barraud.....	2/10	−2.921	−1.809	−1.240	−2.880	−2.889	−2.623	−1.316	−2.230	−3.426	−2.076	−2.169	−1.171	−1.297	−1.194	−1.149
N.	T. S. & J. D. Negus..	1583	−0.243	+0.691	+0.617	−1.023	−1.853	−1.051	+0.077	−0.587	−0.569	−0.040	−0.097	+0.757	+0.381	+0.377	+0.316
N.	....do.....	1452	−1.279	+0.513	+1.617	+0.263	−0.674	−0.337	+0.149	−0.623	−1.854	−0.040	−0.026	+1.364	+1.203	+1.270	+1.030
Bo.	Barraud.....	1509	+1.364	+2.120	+2.331	+0.441	−0.889	−0.944	−0.030	−0.266	−1.176	−0.540	−0.776	−0.100	−0.154	−0.266	−0.327

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APPENDIX B.—*Record of trial of repaired chronometers, January, 1888–July, 1888—Continued.*

	Time		Apr. 27 to May 4.	May 4 to May 11.	May 11 to May 18.	May 18 to May 25.	May 25 to June 1.	June 1 to June 8.	June 8 to June 15.	June 15 to June 22.	June 22 to June 29.	June 29 to July 6.	Temperature of compensation.	Temperature constant.	First trial number.	Final trial number.	Relative number.
	Temperature, Fahrenheit		71°.15	73°.17	71°.14	67°.66	75°.18	73°.15	75°.53	82°.09	83°.56	74°.95					
	Relative humidity, per cent.		58.0	62.7	60.5	62.8	70.1	66.6	68.0	66.7	66.8	62.0					
	Chronometer maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	°	*s.*	*s.*	*s.*	
N.	T. S. & J. D. Negus	1283	−0.934	−0.843	−0.869	−0.730	−0.819	−0.779	−0.740	−1.137	−1.419	−0.724	69.310	−0.00302	10.6997	11.2926	1
N.	do	1343	−0.791	−0.736	−0.869	−0.837	−0.890	−1.064	−1.133	−1.351	−1.347	−1.010	71.028	−0.00318	12.9750	13.7671	2
Bl.	John Hutton	318	+0.673	+0.836	+0 703	+0.734	+0.789	+0.757	+0.689	+.0184	−0.026	+0.240	68.332	−0.00250	8.8287	13.8912	3
N.	T. S. & J. D. Negus	1345	+1.351	+1.443	+1.203	+1.270	+1.396	+1.364	+1.439	+1.113	+1.048	+1.204	73.143	−0.00294	12.5423	14.1299	4
N.	do	1308	−2.541	−2.414	−2.583	−2.516	−2.497	−2.564	−2.526	−2.709	−2.919	−2.689	70.749	−0.00277	12.3224	14.9145	5
N.	do	1273	−0.649	−0.629	−0.583	−0.301	−0.819	−0.707	−0.847	−1.459	−1.704	−1.010	65.265	−0.00313	13.8447	15.2608	6
N.	do	863	+0.780	+0.764	+0.739	+0.913	+0.181	+0.186	+0.046	−0.530	−0.633	−0.010	67.464	−0.00246	8.4756	15.5512	7
N.	do	1245	+0.780	+0.693	+0.846	+1.234	+1.289	+1.186	+1.153	+0.434	+0.510	+1.062	69.612	−0.00313	12.1875	16.2679	8
N.	do	1298	−0.077	+0.050	−0.154	+0.091	−0.140	−0.033	+0.010	−0.459	−0.669	−0.153	68.518	−0.00322	12.2240	16.7609	9
N.	do	1220	+0.244	+0.229	+0.024	+0.234	−0.033	+0.079	+0.081	−0.387	−0.633	−0.153	70.410	−0.00365	16.7511	17.6160	10
N.	do	1259	−1.041	−1.164	−1.011	−0.909	−1.247	−1.064	−1.204	−1.566	−1.847	−1.224	67.302	−0.00341	16.9059	17.9059	11
Bl.	John Hutton	352	−1.006	−1.057	−1.511	−1.087	−1.676	−1.636	−1.526	−1.923	−2.133	−1.474	66.250	−0.00341	15.2604	18.0160	12
Bl.	do	225	+1.066	+1.193	+1.096	+1.127	+1.181	+1.079	+1.189	+0.934	+0.689	+0.847	75.241	−0.00329	17.5206	18.4615	13
N.	T. S. & J. D. Negus	1115	+0.137	+0.229	+0.096	+0.377	+0.039	+0.114	−0.026	−0.744	−1.097	−0.260	64.353	−0.00306	16.6490	20.3739	14
Bl.	John Bliss & Co	2484	+2.601	+2.693	+2.489	+2.520	+2.646	+2.686	+2.903	+2.399	+2.189	+2.704	71.518	−0.00334	19.3613	20.6609	15
N.	T. S. & J. D. Negus	1448	+0.030	+0.014	+0.096	+0.377	+0.217	+0.293	+0.260	−0.244	−0.561	+0.240	62.985	−0.00309	19.9914	21.4555	16
N.	do	740	−1.720	−1.771	−1.940	−1.694	−1.854	−1.779	−1.883	−2.494	−2.847	−2.117	63.423	−0.00357	19.6642	21.5138	17
N.	do	1319	+0.280	+0.300	+0.203	+0.413	+0.324	+0.293	+0.296	−0.101	−0.454	+0.061	66.546	−0.00301	20.5077	22.2238	18
Bo.	John Munroe	275	−1.399	−1.343	−1.619	−1.516	−1.497	−1.529	−1.419	−1.494	−1.561	−1.510	78.709	−0.00171	20.6647	23.1928	19
Bl.	John Bliss & Co	2768	−0.649	−0.450	−1.297	−1.337	−0.997	−1.243	−1.204	−1.030	−1.240	−1.224	88.845	−0.00123	18.5050	25.4746	20
Bo.	Barraud	$\frac{3}{330}$	−1.113	−1.129	−1.333	−0.944	−1.747	−1.636	−1.669	−2.244	−2.526	−1.867	67.520	−0.00492	34.9219	38.0548	21
N.	T. S. & J. D. Negus	1583	+0.316	+0.371	+0.310	+0.449	+0.431	−0.100	−0.061	−0.673	−0.954	−0.117	65.135	−0.00373	36.0753	39.7617	22
N.	do	1452	+1.566	+1.550	+1.453	+1.591	+1.503	+1.507	+1.367	+0.863	+0.439	+0.704	70.073	−0.00413	53.3545	55.6045	23
Bo.	Barraud	1509	−0.256	−0.271	−0.404	−0.266	−0.747	−0.421	−0.490	−1.209	−1.454	−0.617	64.560	−0.003608	127.5806	128.5215	24

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APPENDIX C.

[Report of Commander Allan D. Brown.]

U. S. NAVAL OBSERVATORY,
Washington, October 1, 1888.

SIR: The work of the division of verification of instruments was carried on by Ensign Clements, under my general supervision, until the 1st of July; since that date Mr. Clements has been absent in attendance on the Cincinnati Exposition.

CLASS A.—SEXTANTS AND OCTANTS.

There have been received for examination, prior to repairs, twenty sextants; of these, four have been condemned. There were on hand at date of last report thirty-two sextants; of these, fifteen have been issued to ships in commission, and two sent to the Cincinnati Exposition; sixteen have been repaired, but all have not been critically examined for errors of eccentricity. The total number on hand is thirty-one.

CLASS B.—THERMOMETERS.

At the request of the Supervising Surgeon-General of the Marine Hospital Service, one hundred and nine clinical thermometers were examined and duly returned with a certificate attached to each. Four were broken and thirteen were found to be unreliable, showing a decided improvement over those examined for the same service last year.

A Draper recording thermometer was also received from the agents in this city and placed under comparison. The recording apparatus worked well, but the results of the trial showed that the thermometer did not respond quickly to atmospheric changes, and it can not be regarded as a reliable instrument for use in the service.

CLASS C.—SPY-GLASSES.

Twenty-five spy-glasses, by Elliott Brothers, were received early in the year and duly examined. They were found to be superior to those previously received from the same firm, and have been issued for service. Two other glasses (one by Avizard, of Paris, presented to the observatory by the manufacturer through Lieutenant Winterhalter) have also been examined. The Avizard glass, upon comparison with No. 16 Elliott (retained as a standard), showed optical superiority, and it has been, by the Bureau's direction, made the standard to which in future the optical performance of glasses must attain.

CLASS D.—STATION POINTERS.

No instruments of this class have been examined.

CLASS E.—CLINOMETERS.

One Evelyn's patent ship clinometer has been presented to the observatory by Lieutenant Winterhalter, to whom it was presented by the inventor.

CLASS F.—BAROMETERS.

No instruments of this class have been examined.

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CLASS G.—BINOCULARS.

Twenty-eight pairs of binocular glasses have been submitted for examination; of these, four by Steinheil and two by Avizard (purchased by the Bureau's order by Lieutenant Winterhalter) have been accepted. One "standard" and one "ordinary" by Bardou have also been accepted. Of the others examined, none have been found fully equal to the wants of the service. As one of the results of the examination, it was ascertained that glasses manufactured in Europe and imported into this country have too great a distance between the axes; from which it would appear that the pupils of the eyes of Americans are nearer together than those of Europeans, if the glasses are made with any view to having this distance correct. I am unofficially informed that the same result has been reached by the Signal Service in their search for binoculars. In view of this fact, it was deemed best to recommend the use of a folding frame, by which the distance between the axes of the tubes can be changed from $2\frac{1}{8}$ to $2\frac{3}{4}$ inches to suit individual cases. A scheme for a "standard" glass was devised and forwarded to the Bureau, where it was approved, and three glasses were ordered to be made in accordance with the specifications laid down. One of these (referred to above as the "standard" by Bardou) has been received, examined, and accepted. There were some slight defects in the manufacture, which will undoubtedly be remedied in the next one made; this (together with one by another maker) is promised for a near date. The specifications call for an object-glass of but 1.5 inches in diameter, and 5.5 inches focal length; the oculars are four in number, set in a revolving disk, giving powers from 3 to 6, making the glass suitable for both night and day use. The weight of the instrument is but $20\frac{1}{2}$ ounces, being 13 ounces less than that of the "ordinary" pattern. It is believed that hereafter the service will be supplied with an excellent glass at no great expense.

RECAPITULATION.

The total number of instruments examined is as follows:

Class A.	Sextants	20
	B. Thermometers	110
	C. Spy-glasses	27
	D. Station pointers	0
	E. Clinometers	1
	F. Barometers	0
	G. Binoculars	28
		186

In addition to the above, a reflecting circle, patented by Capt. Charles Henry Townshend, of New Haven, Conn., was examined by a board consisting of Lieutenant Winterhalter, Ensign Clements, and myself. It was found to possess many advantages for use in hydrographic work, and recommended as a valuable addition to the outfit of a vessel.

Very respectfully,

ALLAN D. BROWN,
Commander, U. S. Navy, Assistant Superintendent.

The SUPERINTENDENT, U. S. NAVAL OBSERVATORY.

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APPENDIX D.

[Report of Prof. William Harkness, of the Transit-of-Venus Commission.]

UNITED STATES NAVAL OBSERVATORY,
Washington, October 11, 1888.

SIR: I have the honor to submit the following report of the work done during the past year, under my supervision, for the Transit of Venus Commission:

The assistants employed at the beginning of the year were Messrs. A. S. Flint and H. P. Tuttle. Mr. Tuttle left the service of the Commission on July 31, and since that time Mr. Flint has been the only computer employed.

The work accomplished by Messrs. Flint, Tuttle, and myself may be summarized as follows:

The observations made at the Lick Observatory for determining local time, azimuth, and level of the axis of the photoheliograph, and the interval between the objective and reticule plate of that instrument, were received last December, and were reduced at once. The reduction and discussion of the experiments to determine the radii of curvature of the heliostat mirrors, mentioned in last year's report, has been completed. Additional measurements of the thicknesses of all the reticule plates have been made; their indexes of refraction have been computed from measurements of the linear displacements of small pencils of light passing obliquely through the plates; and the optical thicknesses of all the reticule plates have been deduced, both from the indexes of refraction and from direct measurements effected by focusing a compound microscope alternately through air and through the reticule plates. The focal distances, and positions of the principal points, have been computed from the experiments made in 1884, for all the photographic objectives, and also for each of their component lenses. The measuring rods belonging to nine of the 40-foot photoheliographs have been very carefully compared with each other, and the length of the 10-foot measuring rod which was used in connection with the New Haven photographs has been accurately determined at the office of weights and measures, under the direction of the Superintendent of the U. S. Coast and Geodetic Survey.

The computations of the refractions at Auckland, New Zealand, Lick Observatory, and New Haven, Conn., have been completed, and the differential refractions of Venus relatively to the sun's center have been computed, both in position angle, and distance, for all the stations. The latter work involved the formation of new tables, those used in connection with the 1874 transit being found inadequate. The coefficients of the unknown quantities in the observation equations for determining the solar parallax and the errors of the tables of Venus have been interpolated for Wellington, South Africa; Santa Cruz, Patagonia; Auckland, New Zealand; Princeton, N. J.; the Lick Observatory, California; New Haven, Conn., and the products of these coefficients required for forming the normal equations have been interpolated for Santa Cruz, Santiago, Auckland, Princeton, and New Haven. All the other stations were computed last year.

The method employed in the formation of the absolute terms of the observation equations was as follows: (1) The distances measured upon the photographs between the centers of the sun and Venus were converted into arc without the application of any corrections whatever; and the position angles of Venus relatively to the sun's center and the plumb line were corrected only for such small errors as arose from ac-

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cidental want of coincidence between the center of the sun's image and the center of the reticule plate. (2) From the positions of Venus and the sun given in the American Ephemeris, combined with the known hour angles and refractions, tables were computed for each station, giving for every minute of time the theoretical position angles and distances of Venus relatively to the sun's center upon the photographs. (3) The latter position angles and distances were interpolated to the times of the photographs, and the differences between them and the values measured from the photographs gave at once the absolute terms of the observation equations. By this process the risk of error was reduced to a minimum. It may be well to explain that for the computation of the differential refractions used in the tables just described, a pretty exact knowledge of the errors of the tables of Venus was necessary; and that knowledge was obtained by a preliminary solution of the equations yielded by thirty-three photographs distributed among ten of the stations. Advantage was taken of the knowledge thus acquired to make the absolute terms of the observation equations as small as possible.

The distance equations have been formed from all the photographs, their number and distribution being as follows:

Washington	49	Santiago	197
Cedar Keys	165	Auckland	51
San Antonio	121	Princeton	162
Cerro Roblero	216	Lick Observatory	123
Wellington	180	New Haven	86
Santa Cruz	211		
		Total	1,561

As the New Haven photoheliograph was of an entirely different kind from those used at the other stations, the New Haven equations have been temporarily laid aside for further discussion. The solution of the 1,475 equations, obtained from negatives made with horizontal photoheliographs of about 40 feet focus, has given

$$\pi = 8.847'' \pm 0.012''$$
$$\delta A = +2.893$$
$$\delta D = +1.254$$

where π is the solar parallax, and δA and δD are, respectively, the corrections to the right ascensions and declinations of Venus given by Hill's tables of that planet, it being assumed that Hansen's tables of the sun are correct. The corresponding mean distance from the earth to the sun is 92,385,000 miles, with a probable error of only 125,000 miles. The probable error of a distance between the centers of the sun and Venus obtained from the measurement of a single photograph is $\pm 0.715''$.

It is expected that the formation of the normal equations from the position angles will be completed in about a month, and it may reasonably be anticipated that when the results from them are combined with those from the distances, the probable error of the parallax will be somewhat diminished.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics, U. S. Navy,
of Executive Committee of Transit of Venus Commission.

Capt. R. L. PHYTHIAN, U. S. Navy,
Superintendent Naval Observatory,
President of Transit of Venus Commission.

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APPENDIX E.

[Letter from Lieut. A. G. Winterhalter.]

U. S. NAVAL OBSERVATORY,
Washington, October 9, 1888.

SIR: I had the honor of reporting my return to the United States from Europe by letter to the Department, dated New York, November 25, 1887, and in person to the Superintendent on November 29.

During my absence, in addition to the cities mentioned in the last annual report of the Superintendent, I visited, under orders of the Department, observatories and establishments of a scientific character in the following places: Meudon, France; Greenwich, Richmond, Ealing, Oxford and Cambridge, England; Leyden, Holland; Düsseldorf, Bonn, Strasburg, Berlin, Potsdam, Dresden, Leipsic and Munich, Germany; Vienna, Austria. It is a duty to say that I was everywhere cordially welcomed as the representative of the Observatory. I trust I may be permitted to indulge the hope that my visits have done good in fostering the kindly relations uniting us to European astronomical institutions. The details of my proceedings are given in the full report which is now in preparation, and which I shall have the honor to submit at an early date.

For the numerous courtesies of which I was the recipient, I beg leave in this manner to present my earnest thanks to those with whose acquaintance I was favored.

I was the bearer of sundry plans, drawings, sketches and photographs, sixty-five in number, which were at various times presented through me to the Observatory, as also of one hundred and thirty-four books, pamphlets and catalogues donated to the library; a list of these presents I shall include in my report.

The following instruments were brought to the Observatory:

One ship's clinometer, presented to me by Col. G. P. Evelyn and by me donated to the Observatory.

One Evelyn's patent bubble-horizon, purchased and tested at sea by order of the Bureau of Navigation.

One sextant-mirror testing apparatus, by G. Hechelmann, Hamburg; purchased by order of the Superintendent.

One pair of high-power binoculars, by MM. R. & C. Avizard, Paris; purchased by order of the Bureau of Navigation.

One pair of low-power binoculars, by MM. R. & C. Avizard, Paris; purchased by order of the Bureau of Navigation.

One marine spy-glass, presented to the Observatory by MM. R. & C. Avizard, Paris.

One pair of high-power binoculars, by HH. C. A. Steinheil Söhne, Munich; submitted for examination and since purchased for trial in the service.

One pair of low-power binoculars, by HH. C. A. Steinheil Söhne, Munich; submitted for examination and since purchased for trial in the service.

One marine spy-glass, by HH. C. A. Steinheil Söhne, Munich; submitted for examination; since returned.

One Jena-glass telescope, aperture 36 Par. lines, with a number of eye-pieces of a variety of constructions, by HH. C. A. Steinheil Söhne, Munich; on trial.

Also, one box of pieces of Jena optical glass, presented by Dr. Adolph Steinheil.

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One sextant with "gyroscope-collimator" and attachments, by M. A. Hurlimann, Paris, the invention of Capt. G. Fleuriais, French Navy; purchased and tested at sea by order of the Bureau of Navigation.

During the month of December, 1887, I was engaged principally in making the official reports incident to my return and in drawing up the reports on such of the instruments named as had been tested by me. During July and August, 1888, I was employed in preparing the illustrative and photographic exhibit of the Observatory for the Cincinnati Exposition, while during the month of September I had miscellaneous work. During the remaining six months I have been at work by your order in preparing a report on the results of my observation while in Europe, including an account of the International Astrophotographic Congress, held in Paris, April, 1887. The latter, which forms Part I of the report, comprises 166 manuscript pages and is now in the hands of the Public Printer.

In this connection I beg leave to recommend to your consideration the urgency of a provision to enable the Observatory to do the work which will fall to its share in charting the sky by photographic processes. Already foreign governments have been responding liberally with the necessary funds to allow their observatories to take part in the concerted operations; Germany, England, Brazil, Chili, Spain, Mexico and the Argentine Republic have each one instrument in process of construction; Australia has two photographic telescopes under way, while France has one completed at Paris and three others in the hands of a constructor. Besides, according to my information, instruments of the character prescribed by the congress will, without much doubt, be also built for other observatories in England, Denmark, Austria and Russia. Only one of the thirteen instruments whose construction is assured has been provided by private means and that for an established university observatory. The character and extent of the projected work will exclude the co-operation of private observatories. It is respectfully submitted that the United States, "the home of astronomical photography," is likely to be left without representation in this great international undertaking should the Naval Observatory not be provided with means for doing the share which will naturally be allotted to it.

Very respectfully, your obedient servant,

A. G. WINTERHALTER,
Lieutenant, U. S. Navy.

The SUPERINTENDENT, NAVAL OBSERVATORY,
Washington.

ADDENDUM.

CINCINNATI EXPOSITION.

U. S. NAVAL OBSERVATORY,
Washington, October 30, 1888.

SIR: I have the honor to inclose the reports of Commander A. D. Brown, Lieut. A. G. Winterhalter, and Ensign A. B. Clements on the Observatory exhibit at the Centennial Exposition of the Ohio Valley and Central States, held at Cincinnati, Ohio, with the suggestion that they be appended to the annual report of the Superintendent of the Observatory.

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The thanks of the Observatory are due to Mr. T. W. Smillie, of the National Museum, for valuable assistance in preparing the photographic exhibit.

Commander Brown, Lieutenant Winterhalter, Ensign Clements, and Mr. Gardner performed their respective duties in connection with the preparation of the exhibit very efficiently. Through their efforts the principal parts of it were in place at the opening of the Exposition, notwithstanding the late date at which the appropriation became available.

Very respectfully,

R. L. PHYTHIAN,
Captain, U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF NAVIGATION,
Navy Department.

UNITED STATES NAVAL OBSERVATORY,
Washington, October 29, 1888.

SIR: In compliance with your directions, I have the honor to submit an account of the Observatory exhibit at the Cincinnati Exposition.

As soon as the appropriation became available the preparations for shipment began. The preparation of the photographic portion of the exhibit was intrusted to Lieut. A. G. Winterhalter, who devoted much time and attention to this duty. The result of his labor was a series of photographs of the Observatory, instruments, etc., much more complete than the Observatory has ever before possessed. The report made by him gives a list of the portion of the exhibit so prepared.

The time-service exhibit was a complete representation of the system pursued in the distribution of time by the Observatory, and consisted of—

(1) Astronomical clock, with transmitting attachment.*
(2) Chronograph.
(3) Transit instrument.
(4) Relays, sounders, repeaters, etc., for distribution of signals in the exhibition building.
(5) Time-ball.
(6) Gardner clock to show intercolonial (or sixtieth meridian) time.
(7) Gardner clock to show eastern (or seventy-fifth meridian) time.
(8) Gardner clock, showing central (or ninetieth meridian) time.
(9) Gardner clock, showing mountain (or one-hundred and fifth meridian) time.
(10) Gardner clock showing Pacific coast (or one hundred and twentieth meridian) time.
(11) Time-gongs.
(12) Map showing 30,000 miles of railroad receiving the time-signals from the Observatory.
(13) Map showing the different divisions of the standard-time system.

In addition to this were three houses of the Transit-of-Venus Commission pattern, containing, respectively, a photoheliograph, an equatorial telescope of 5-inch aperture, and the transit instrument mentioned above. There was also sent for exhibition a magnetometer, with a dip circle of the Transit-of-Venus Commission pattern.

All the articles mentioned above were shipped from the Observatory by the 30th of June, and were at the Exposition building before it was

*Property of Seth Thomas Clock Company.

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entirely ready for their reception. The packing and work of preparation therefore were done by Mr. William F. Gardner, to whom much credit is due for the promptness with which the work was performed.

Very respectfully,

ALLAN D. BROWN,
Commander, U. S. Navy, Assistant Superintendent.

The SUPERINTENDENT, U. S. NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, October 9, 1888.

SIR: The illustrative and photographic exhibit of the Observatory at the Centennial Exposition of the Ohio Valley and Central States, held at Cincinnati, Ohio, the preparation of which was by your order intrusted to me, was forwarded to that city in July and August last.

I have the honor to submit herewith a list of frames displayed.

List of frames displayed.

No.	Size of illustration.	Description.
	Inches.	
1	14 x 46	Drawing: Elevation of main building, New Naval Observatory.
2	14 x 46	Drawing: Section of same.
3	16½ x 41	Drawing: The new great dome.
4	22 x 28	Photograph: Time-ball station at Telegraph Hill, San Francisco.
5	22 x 48	Photographs: Curves of declination, horizontal and vertical forces, typical of ordinary, moderately disturbed, and greatly disturbed conditions of terrestrial magnetism.
6	27 x 40	Photograph: Group of members of International Astrophotographic Congress, by Nadar, Paris.
7	20 x 26	Three photographs of phases of solar eclipse; three of transit of Venus; taken with the horizontal photobeliograph.
8	30 x 40	Eight drawings showing the workings of the Gardner Observatory time system, arrangements of transmitting clocks and time-balls.
9	27 x 40	Photographic enlargement: Grounds of New Naval Observatory and location of projected buildings.
10	30 x 40	Photograph: The great dome and prime-vertical room.
11	30 x 40	Photograph: The smaller dome and adjacent parts of main building.
12	30 x 40	Photograph: The transit-circle building.
13	30 x 40	Photograph: Compass-house No. 1.
14	30 x 40	Photograph: Compass-house No. 2.
15	34 x 40	Nine views of buildings and instruments.
16	34 x 40	Do.
17	34 x 40	Do.
18	16 x 18½	Photograph: Transit instrument and mural circle.
19	16 x 18⅜	Photograph: The transit circle.
20	16 x 18⅜	Photograph: The great equatorial.
21	16 x 18⅜	Photograph: The 9.6-inch equatorial.
22	25 x 28	Drawing of Omega nebula, as seen through the great equatorial.
23	25 x 36	Drawing of Orion nebula, as seen through the great equatorial.
24	30 x 36	Drawing of Saturn, as seen through the great equatorial.
25	17 x 22	Drawing of Ring-Nebula in Lyra, as seen through the great equatorial.
26	30 x 36	Photograph: Solar Eclipse, March 15–16, 1885; diameter of Sun's disk, 26 inches.
27	20 x 26	Drawing: Total eclipse of the Sun, July 29, 1878.

The above illustrations, with few exceptions, were newly made for the purpose in hand. In the execution of several of them I had the efficient and valuable assistance of Mr. T. W. Smillie, of the National Museum, freely given in the midst of his own exacting labors, the Secretary of the Smithsonian Institution, Prof. S. P. Langley, having accorded the necessary facilities at the request of the Superintendent.

In response to a letter of Prof. J. Brown Goode, assistant secretary in charge of the National Museum, addressed to the Superintendent, a

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number of photographs were furnished that institution, showing the uses of photography in representing lunar, solar, and stellar phenomena, and in recording changes in the earth's magnetic forces and including views of instruments used for such purposes. Copies of these, I am informed, were exhibited at Cincinnati, and on their return to Washington will form part of an interesting exposition of the history of photography prepared for the Museum by Mr. Smillie.

Very respectfully, your obedient servant,

A. G. WINTERHALTER,
Lieutenant, U. S. Navy.

The SUPERINTENDENT, U. S. NAVAL OBSERVATORY,
Washington.

U. S. NAVAL OBSERVATORY,
Washington, October 29, 1888.

SIR: I have the honor to submit the following statement concerning the exhibit of the Naval Observatory at the Centennial Exposition of the Ohio Valley and Central States, held at Cincinnati, Ohio.

I reached Cincinnati June 29, several days before the opening of the exposition, and remained there until detached, October 23.

The space allotted to the exhibit of the Navy Department was the southern part of the east wing of the Park Building and the northeastern part of the south wing of the Government annex. Of this the Observatory exhibit was assigned a platform about 6 inches high and some 36 feet long by 12 wide along the northern wall of the annex building, which seemed admirably adapted for the purpose.

The building was not completed until July 2, at which time we began unpacking and placing the exhibit. The time-service exhibit was the first to be placed in position and was in operation at the time of the opening of the exposition, July 4. Every facility for the receipt of signals and all the assistance in their power was cheerfully given us by the officials of the Western Union Telegraph Company; to Manager Page, of the Cincinnati office, we were specially indebted for valuable aid. A special wire was run from the local office to the Observatory exhibit for the use of the time-service, and was so carefully attended to that no fault occurred in that circuit during the exposition. This line and one of the Observatory time-gongs were used in opening the exposition, signals from Mrs. James K. Polk, at Nashville, Tenn., being struck on the time-gong temporarily placed on the Music Hall stage for that purpose.

The disposition of the exhibit was generally as follows: The sidereal clock, chronograph, Gardner clocks, telegraphic instruments, maps, photographs, drawings, and magnetic instruments were placed on the platform in the naval exhibit. The time-gongs were placed, one near the fountain in the center of Park Building, the other over the canal in machinery hall; a third gong, a part of the exhibit of the Ohio State University, was connected with the same circuit and struck by the time signals. The time-ball was placed on a platform 16 feet high and 8 feet square, erected on the tower over the main entrance to the Park Building, on Elm street. The observatory houses, the photoheliograph and heliostat, equatorial, and transit houses, with their instruments set up for use, were placed in the southeast corner of the park, just outside the Government annex.

Five clocks of the Gardner system, showing intercolonial, eastern, central, mountain, and Pacific coast time, respectively, were kept run-

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ning continually and were corrected daily by the noon signal. The clocks and time-ball gave no trouble whatever, responding promptly and accurately to every signal. The time signals were received with the greatest regularity; we failed to receive them on only about half a dozen occasions during the one hundred days, and only once failed by reason of a fault outside the local line in Washington City.

The observatory houses in the park were open to the public for two hours, from 1 to 3, each afternoon, and the photoheliograph image of the sun was shown every day on which the sun was visible. The equatorial house was open on clear nights, and an opportunity to view the heavens through the telescope was afforded many visitors.

I believe the Observatory exhibit was an attractive feature of the Government display, the time-service especially attracting much attention.

Very respectfully, your obedient servant,

A. B. CLEMENTS,
Ensign, U. S. Navy.

Capt. R. L. PHYTHIAN, *U. S. Navy,*
Superintendent, U. S. Naval Observatory, Washington, D. C.

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[REPORT OF THE SECRETARY OF THE NAVY, 1889. pp. 414–425.]

REPORT

OF

THE SUPERINTENDENT

OF THE

U. S. NAVAL OBSERVATORY

FOR THE

YEAR ENDING JUNE 30, 1889.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1889.

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REPORT

OF THE

SUPERINTENDENT OF THE U. S. NAVAL OBSERVATORY.

WASHINGTON, 1889.

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REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, August 19, 1889.

SIR: I have the honor to submit, in compliance with the Bureau's order of the 6th instant (No. 1816 *b*) the report of the Naval Observatory for the fiscal year ending June 30, 1889.

The following changes in the personnel have occurred. Detachments: Commander A. D. Brown, on October 30, 1888; Lieut. William P. Elliott, March 13, 1889; Lieut. L. C. Heilner, April 18; Lieut. A. G. Winterhalter, April 29; Ensign A. N. Mayer, April 19, 1889. Assistant Astronomer William C. Winlock resigned May 14, 1889. Reported for duty: Lieut. Hiero Taylor, November 27, 1888; Lieut. W. O. Sharrer December 20, 1888, and Ensign J. A. Hoogewerff, June 1, 1889.

DIVISION OF WORK—OFFICERS IN CHARGE.

Assistant to Superintendent.—This office ceased to exist on the detachment of Commander Brown, and the duties formerly pertaining to it have, since December, been performed by Lieutenant Sharrer.
Chronometers and time service.—Lieut. Hiero Taylor.
East transit instrument.—Lieut. B. W. Hodges.
Inspection of instruments.—Ensign A. B. Clements.
Magnetic instruments.—Ensign C. C. Marsh.
Great equatorial.—Prof. Asaph Hall.
Transit circle.—Prof. J. R. Eastman.
9.6-*inch equatorial.*—Prof. Edgar Frisby.
Library.—Assistant Astronomer H. M. Paul.
Instrument-maker.—William F. Gardner.
Clerk.—Thomas Harrison.

The meteorological observations were made by the watchmen, Dennis Horigan, Nicholas Cahill, and William Henderson.

Prof. William Harkness is also attached to the Observatory for special duty as the member of the Transit of Venus Commission, having direct charge of the reductions and computations of the observations of 1874 and 1882. His report of the progress of the work is hereto appended, marked Appendix B.

THE GREAT EQUATORIAL.

(Professor Hall, in charge.)

This instrument has been employed in observing double stars and the satellites of Saturn. Attention was also given to the appearance of this planet, to the divisions of the ring, and to the shadows. As the satellite Iapetus had returned to nearly the same apparent position with respect to Saturn that it had in 1875, a new series of observations by the method of differences of right ascension and declination was made at the last opposition. These have been reduced and are nearly ready for discussion. The drawings of Saturn have been finished, and the notes on the appearance of the planet made since 1875 have been sent to the printer. These drawings and notes will appear as Appendix II to the volume for 1885.

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Ensign H. S. Chase has been employed on the work of this instrument, in revising the reductions and in preparing the observations for publication.

Mr. George Anderson has had charge of the dome and the gas-engine.

The instrument is in good order.

THE TRANSIT CIRCLE.

(Professor Eastman, in charge.)

The transit circle has been employed on observations of the sun, moon, major and minor planets, and such stars as were necessary for clock and instrumental corrections. The observation of a small list of stars for the U. S. Coast and Geodetic Survey has also been undertaken.

The assistants on the work of this instrument have been Assistant Astronomer A. N. Skinner; Assistant Astronomer H. M. Paul, to November, 1888; Assistant Astronomer W. C. Winlock, to May 14, 1889; Computer William M. Brown; Computer A. S. Flint, since November 24, 1888.

From October 9, 1888, to June 30, 1889, 1,700 observations were made with the transit circle. Of this number 68 were of the sun, 50 of the moon, 93 of the major planets, 18 of the minor planets, and 5 of Comet *e* 1888. Clock signals were exchanged with Buchtel College Observatory, Akron, Ohio, on six nights in December and January to determine the longitude of that observatory.

The reduction of the observations which have been accumulated with this instrument has delayed observations on the zone of stars for the German Astronomical Society.

The transit circle work for 1885 is nearly ready to be copied for the printer, and the reductions for 1886 are now in hand.

But one of the two additional computers estimated for last year was authorized by Congress; he has not yet been appointed. The other is asked for in the estimates recently submitted. It is earnestly hoped that the services of both, so greatly needed, may be obtained.

THE 9.6-INCH EQUATORIAL.

(Professor Frisby, in charge.)

This instrument has been used for the identification of stars whenever necessary, and for the observation of small planets, comets, and occultations of stars by the moon. Three comets have been seen, and observed whenever possible; the observations have all been reduced and published in the *Astronomical Journal*. Two evenings in the week have been set apart for the accommodation of visitors. Permits for 1,665 visitors were issued.

The revision of Yarnall's Catalogue of Stars has been completed, and the work is nearly ready for distribution.

VARIABLE STARS.

For the last year and a half, Assistant Astronomer H. M. Paul has been engaged upon observations of a list of stars which have at various times been suspected of variability in brightness. One of the results of this work has been the discovery of a new variable in the constella-

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tion *Antlia*, with a period of less than twelve hours, the shortest period yet known. These observations will be published as soon as they can be prepared for the printer.

CHRONOMETERS AND TIME SERVICE.

(Lieutenant Taylor, in charge.)

Lieutenant Taylor reported for duty November 27, 1888. Ensign Mayer had been in charge up to that time and continued on duty here until April 19, 1889, when he was detached.

The records show that during the year chronometers have been issued to eleven ships and one shore station. Chronometers have been received from the same number of ships and shore stations. The chronometers received from the *Nipsic* and the *Vandalia* were so damaged that they have not been sent to the makers for repairs; other chronometers received were sent to the makers for necessary repairs. Two box chronometers have been condemned for use as hack-chronometers. In October, 1888, fourteen chronometers were purchased. Fifty-six chronometers received from makers, cleaned and repaired, were placed under trial in the temperature-room December 23, 1888, and kept there until March 6, 1889. The routine observed in the temperature-room was the same as for the trial of 1887–88. The only mishap occurred two days before the end of the last term at 45°, when a leak from the ice-chamber was discovered. The chronometers were not injured, and the trial in the chronometer-room has been completed. The records of this trial are given in Appendix A. The following table shows the number and disposition of the chronometers belonging to the Government at the end of the fiscal year:

Disposition of chronometers.	Box.	Hack.	Disposition of chronometers.	Box.	Hack.
Ready for issue	21	1	Repairing	32	2
Issued	145	73	Loaned	3	3
Trial	56				
For repairs	25	136	Total	282	215

In addition there are: 7 chronometric watches, 6 hack-chronometric watches, 4 comparing watches.

No changes have been made in the routine of sending out time signals. The signals are sent every day, Sundays and holidays excepted, over the wires of the Western Union Telegraph Company, and time-balls are dropped at noon, 75th meridian, at Boston, Wood's Holl, Newport, New York, Philadelphia, Baltimore, Hampton Roads, Savannah, and New Orleans. The Washington time-ball is worked by signals over a Government wire leading from the Observatory to the State-War-and-Navy building. With the single exception of Newport, the Observatory receives no reports from time-ball stations. Such reports, if it were possible to get them, would be valuable.

The signals have also been used to correct the clocks on the Observatory clock line. This service has been on the whole satisfactory. The only serious trouble occurred in September, 1888, when the line was grounded in the new Government cable. The clocks up to the ground were corrected as usual, and beyond it by the use of a battery loaned by the Western Union Telegraph Company, the signals being repeated from the company's office. The line is in good condition now, and the service is so satisfactory that there is a demand for its extension to all the Government buildings.

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EAST TRANSIT INSTRUMENT.

(Lieutenant Hodges, in charge.)

Lieutenant Heilner was in charge until April 18, and was succeeded by Lieutenant Hodges.

The instrument and all its connections are in good condition. The clocks have performed well. Observations have been taken to determine the corrections of the clocks whenever the weather permitted. Owing perhaps to the excessive amount of rainy weather the standard mean time clock has acquired a steady gaining rate of from two to three tenths of a second a day, having previously had a small losing rate.

INSPECTION OF INSTRUMENTS.

(Ensign A. B. Clements, in charge.)

Class A, sextants and octants.—There were on hand at the time of the last annual report thirty-one sextants; eight have been received from Fauth & Co., having been repaired, and eight have been issued to ships in commission, leaving thirty-one now on hand. Of these, four are small hydrographic sextants, all ready for issue, and twenty-seven are of full size. Of the large sextants, twenty-two are in good condition for issue.

Class B, thermometers.—A Draper recording thermometer similar to the one examined last year was received from the agents in this city and placed under comparison. The results of this comparison only emphasized the conclusions of the previous trial. The recording apparatus works well, but the thermometer does not respond quickly to changes of temperature, and it can not be regarded as a reliable instrument for use in the service.

Class C, spy-glasses.—There have been received from various makers five spy-glasses, which were carefully examined, but they were not recommended for use in the service, and they have been returned to their owners.

Class D, station pointers.—No instruments of this class have been received for examination.

Class E, clinometers.—None received for examination.

Class F, barometers.—None received for examination.

Class G, binocular glasses.—Sixty-one binoculars have been examined. Of these twenty-seven were of the pattern referred to in the last annual report, and twenty were purchased; six were found defective and returned to makers, and one still awaits action. The remaining thirty-four, embracing many different constructions, were carefully examined, but, being found to be unsuited to the use of the service, were returned to the makers.

There are now on hand three; one the property of Levy, Dreyfus & Co., New York, one of the novel construction patented by Steinheil & Son, retained as a sample but unfit for issue, and one, a standard glass, in good condition.

RECAPITULATION.

	On hand at last report.	Received.	Issued.	Returned to maker.	On hand.
Sextants	31	8	8	.....	31
Thermometers	2	1	.....	1	2
Spy-glasses	1	5	.....	5	1
Binocular glasses	3	61	21	40	3

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MAGNETIC INSTRUMENTS.

(Ensign Marsh, in charge.)

Lieut. Wm. P. Elliott was in charge until March 13, 1889, when he was succeeded by Ensign C. C. Marsh, with Ensign J. A. Hoogewerff as an assistant since June 1.

The self-recording magnetometer has been in operation continuously, with the exception of about ten days, from January 1 (when all the magnetographs were examined, cleaned, and, when necessary, readjusted), and an occasional stoppage of the clock, caused generally by the balance arrangement of the shades getting out of order. A new agate knife-edge was fitted to the vertical-force magnetograph, and has worked satisfactorily. As no change was made in the distance of the mirror of the declination magnetograph from the recording cylinder, the value of last year was retained, viz:

Declination.—One centimeter of ordinate=11′.29 of arc.

The value of 1 millimeter of ordinate of the horizontal and vertical-force magnetographs has been determined, at intervals of about one month, by the method of double deflections, the last, on June 12, giving—

Horizontal force, 1^{mm} of ordinate=.00004687 c. g. s. units.

Vertical force, 1^{mm} of ordinate=.00004302 c. g. s. units.

The temperature co-efficients of the H. F. and V. F. magnetographs have been determined by experiment once every three months, the last, June 13, giving—

Horizontal force, change of 1° C.=1.47 millimeters.

Vertical force, change of 1° C.=1.61 millimeters.

Observations of absolute declination have been taken twice a day, generally between 9 and 10 a. m. and 3 and 4 p. m., and from them the value of the photographed base-lines of the declination magnetographs is deduced. The performance of the large declination magnet and theodolite is good.

Observations have been made on Tuesday of each week for the determination of the absolute horizontal intensity, and once each month they have been made with the inertia cylinder attached to the magnet. The magnetometer and magnets are in good order.

Observations of the magnetic inclination have been made, using three needles in rotation, in the forenoon and afternoon of every Monday and Friday. The dip circle and needles are in good condition.

Drawings of the composite curves, taken from the declination magnetograms, are made for each month and negatives taken from them, so that prints can be made to send to other observatories and persons interested in terrestrial magnetism.

A full set of original photographs of the curves (of which there are now two—made by using two papers on each cylinder) is sent to Kew each month.

This division has been furnished with copies of the magnetograph curves of declination from Toronto and Los Angeles. All disturbed days are selected, and a comparison of the disturbances is made by tracings of the curves reduced to the same scale and placed over each other. These tracings are copied on blue or "nigrosine" paper, and the prints sent to observatories and persons interested.

The results of the observations, besides being recorded in figures, are, when practicable, put in the form of curves, so that all changes and variations in the terrestrial magnetism can be readily seen and compared with the occurrence of other natural phenomena.

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Two seismoscopes and a seismograph have been purchased and set up within a few months, and are in good working order. They are examined from time to time, and the clocks connected with the seismoscopes are carefully rated. The seismoscopes are of the Rose-Polytechnic-Institute pattern; one is in the basement of the magnetograph building, with the seismograph, Lick-Observatory pattern, and the other is on a pier in a small building not in use at present.

THE INTERNATIONAL ASTROPHOTOGRAPHIC CONGRESS, ETC.

The preparation of the report, upon which Lieut. A. G. Winterhalter had been engaged up to the time of his detachment from the Observatory, was continued by him at the torpedo station in addition to his other duties.

The manuscript of Part I, comprising an account of the International Astrophotographic Congress, was sent to the Public Printer in September last; the remainder, containing the details of a visit to various European observatories under orders of the Department, has since been forwarded to the printer. Proof has been received and read since May last, and an early completion of the printing of the report may be expected.

THE LIBRARY.

(Assistant-Astronomer Paul, in charge.)

The library contains, according to the accession book, up to June 30, 12,226 volumes and 2,696 pamphlets. The accessions since the date of the last report have been 308 in number, 235 volumes and 73 pamphlets. Of these, 209 were received as exchanges and 99 by purchase.

The exchange list has been recently revised, and now contains 1,278 names, distributed as follows: Home institutions, 321; individuals, 244; foreign institutions, 244; individuals, 469. In the distribution of the observatory publications the general rule is to send the annual volumes to institutions and the separate reprints of the astronomical appendices to individuals.

The following publications are in the hands of the printer, and will soon be issued:

1. The annual volume for 1884.
2. 1884, Appendix I. A third edition of Yarnall's Catalogue of Stars, prepared by Professor Frisby.
3. 1885, Appendix I. International Astrophotographic Congress, by Lieut. A. G. Winterhalter.
4. 1885, Appendix II. Saturn and its Ring, by Professor Hall.

Assistant-Astronomer Paul has recently been placed in charge of the library in addition to other duties. The services of a librarian's assistant, for which estimates have been submitted, are very much needed.

Very respectfully,

R. L. PHYTHIAN,
Captain, U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF NAVIGATION.

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APPENDIX A.—*Record of trial of repaired chronometers*, 1888–'89.

[In temperature room from December 23, 1888, to March 6, 1889; after that date in chronometer room.]

Time				Dec. 23 to Dec. 30	Dec. 31 to Jan. 7	Jan. 8 to Jan. 15	Jan. 17 to Jan. 24	Jan. 25 to Feb. 1	Feb. 2 to Feb. 9	Feb. 12 to Feb. 19	Feb. 21 to Feb. 28	Mar. 1 to Mar. 6	Mar. 6 to Mar. 13	Mar. 13 to Mar. 20	Mar. 20 to Mar. 27	Mar. 27 to Apr. 3
Temperature, Fahrenheit				44°.93	55°.12	69°.91	85°.00	89°.93	84°.88	70°.11	54°.96	45°.70	57°.16	62°.16	61°.86	63°.13
Relative humidity, per cent				70.7	68.7	70.7	66.4	61.9	61.0	63.4	64.0	69.0	55.0	64.0	62.0	64.0
	Repaired by—	*No.*	*Maker.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	Negus	1334	T. S. & J. D. Negus	+0.487	+1.463	+1.631	+0.647	−0.006	+0.853	+1.511	+1.121	+0.510	+1.576	+1.659	+1.740	+1.734
2	....do	1655	.....do	−0.941	−0.394	−0.369	−0.889	−1.399	−1.111	−0.703	−0.307	−0.640	+0.004	−0.091	−0.153	−0.051
3	....do	1454	.....do	−1.299	−0.037	+0.203	−0.781	−1.470	−0.576	+0.083	−0.271	−0.890	+0.433	+0.409	+0.633	+0.627
4	....do	1444	.....do	−1.977	−0.287	+0.024	−0.389	−1.149	−0.290	+0.261	−0.771	−1.590	−0.174	−0.163	−0.117	−0.016
5	....do	950	.....do	−1.191	+0.320	+0.774	+0.326	−0.399	−0.147	+0.547	−0.164	−0.640	+1.397	+1.516	+1.276	+1.663
6	Bond	199	Wm. Bond & Son	+1.201	+1.963	+1.881	+0.647	−0.399	+0.496	+1.761	+1.657	+1.260	+1.897	+2.051	+2.026	+2.091
7	....do	2007	Poole	−0.941	+0.963	+2.060	+2.219	+1.994	+2.531	+2.047	+0.729	−0.540	+0.826	+1.266	+1.383	+1.770
8	....do	294	Wm. Bond & Son	+4.559	+3.856	+2.274	+1.290	+0.780	+1.389	+2.476	+3.407	+4.310	+3.361	+3.159	+3.026	+2.984
9	....do	446	.....do	−0.227	+0.892	+0.631	−0.710	−1.577	−0.647	+0.761	+0.586	+0.060	+0.504	+0.551	+0.490	+0.663
10	Negus	1293	T. S. & J. D. Negus	−1.727	−0.680	−0.797	−1.460	−2.041	−1.576	−1.239	−1.807	−2.240	−1.139	−1.020	−0.939	−0.801
11	....do	1738	.....do	+1.201	+0.463	+0.310	+0.326	+0.066	+0.174	−0.203	−0.379	+0.060	+0.040	+0.194	+0.169	+0.199
12	....do	1272	.....do	−2.549	−1.323	−0.761	−1.460	−2.220	−1.611	−1.024	−1.986	−2.990	−1.674	−1.234	−1.224	−1.016
13	Bliss	1081	De Silva	−0.834	+0.677	+1.310	+0.326	+0.327	+0.317	+1.119	+0.336	−0.740	+0.826	+1.087	+1.097	+1.234
14	Negus	1120	T. S. & J. D. Negus	−1.513	−0.180	+0.739	+0.540	+0.030	+0.281	+0.583	−0.593	−1.440	−0.031	+0.159	+0.204	+0.341
15	....do	725	.....do	−0.620	+0.284	+1.167	+1.183	+0.673	+1.210	+1.297	+0.693	+0.060	+0.219	+0.444	+0.669	+0.949
16	....do	1520	.....do	−1.536	−0.217	−0.390	−1.731	−2.704	−1.880	−0.613	−0.753	−1.144	−0.190	−0.359	−0.027	−0.161
17	....do	1597	.....do	−1.191	−0.430	−0.476	−0.567	−0.899	−0.790	−1.024	−1.236	−1.640	−1.031	−0.984	−0.867	−0.766
18	....do	1234	.....do	−1.906	−0.394	−0.476	−1.210	−1.970	−1.004	−0.096	−0.200	−1.490	+0.217	+0.444	+0.454	+0.699
19	....do	1266	.....do	−1.477	−0.430	+0.453	−0.317	−1.006	−0.361	+0.333	−0.593	−1.490	−0.317	+0.194	+0.169	+0.341
20	Bliss	2149	John Bliss & Co	−1.156	+0.249	+0.560	−0.639	−1.256	−0.719	+0.261	−0.307	−0.990	+0.504	+0.944	+0.811	+1.234
21	Bond	397	Edwards & Hunter	−0.977	+0.677	+0.381	+0.290	−0.613	+0.281	+0.761	−0.236	−1.340	+0.004	+0.409	+0.490	+0.734
22	....do	2507	Barraud	−1.156	+0.427	+1.096	+0.361	−0.113	+0.496	+1.119	−0.057	−0.890	+0.790	+1.123	+1.240	+1.377
23	Negus	1195	T. S. & J. D. Negus	−3.084	−1.323	−0.333	−0.603	−1.041	−0.504	+0.047	−0.950	−1.940	−0.603	+0.016	+0.097	+0.306
24	....do	718	.....do	−1.049	+0.213	+0.131	−1.281	−2.399	−1.611	+0.083	−0.271	−0.840	+0.290	+0.480	+0.526	+0.591
25	....do	190	.....do	−1.441	−0.180	+0.167	−0.567	−1.220	−0.469	+0.333	−0.271	−0.340	+0.897	+1.159	+1.240	+1.020
26	....do	1315	.....do	−2.120	−0.751	−0.440	−2.103	−2.970	−2.147	−0.881	−1.807	−2.290	−0.889	−0.734	−0.903	−0.909
27	....do	991	.....do	−2.870	−1.073	−0.261	−1.389	−2.077	−1.611	−1.024	−1.950	−3.090	−1.103	−0.699	−0.796	−0.480
28	Bond	4613	Thomas Adams	−1.334	+0.677	+0.917	+1.361	+0.280	+0.710	+1.511	+0.657	−1.090	+1.076	+1.444	+1.454	+1.520
29	....do	293	Wm. Bond & Son	−0.834	−0.109	−0.047	−1.424	−2.327	−1.397	−1.489	−1.129	−1.140	−0.424	−0.091	−0.367	−0.337
30	Negus	1684	T. S. & J. D. Negus	−1.709	−0.489	−1.033	−1.590	−2.667	−2.272	−1.184	−0.896	−2.040	−1.297	−1.573	−1.813	−1.854
31	Bond	505	Wm. Bond & Son	−4.799	−3.251	−2.261	−2.174	−1.791	−2.254	−3.560	−3.593	−4.490	−2.996	−3.056	−3.189	−2.980
32	Bliss	29480	Dent	−3.299	−2.537	−1.654	−0.889	−0.077	−0.076	−1.167	−2.057	−2.340	−1.496	−1.199	−1.260	−0.766

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APPENDIX A.—*Record of trial of repaired chronometers*, 1888-'89—Continued.

[In temperature room from December 23, 1888, to March 6, 1889; after that date in chronometer room.]

Time	Apr. 3 to Apr. 10	Apr. 10 to Apr. 17	Apr. 17 to Apr. 24	Apr. 24 to May 1	May 1 to May 8	May 8 to May 15	May 15 to May 22	May 22 to May 29	Temperature of compensation.	Temperature constant.	First trial number.	Final trial number.
Temperature, Fahrenheit	61°.89	64°.72	68°.13	68°.29	66°.84	76°.83	75°.46	67°.66				
Relative humidity per cent	61.4	75.0	68.3	62.7	62.5	65.2	75.1	67.9				

	Repaired by—	No.	Maker.	s.	s.	s.	s.	s.	s.	s.	s.	°	°	s.	s.
1	Negus	1334	T. S. & J. D. Negus	+1.556	+1.744	+1.524	+1.730	+1.640	+1.366	+1.417	+1.603	66.31	−0.002440	9.1549	9.6661
2	....do	1655	.....do	−0.266	−0.256	−0.619	−0.770	−0.881	−0.991	−1.190	−0.969	52.46	−0.000617	7.6887	9.8291
3	....do	1454	.....do	+0.520	+0.459	+0.774	+0.909	+0.783	+0.473	+0.480	+0.496	66.49	−0.002490	9.4419	10.7369
4	....do	1444	.....do	−0.194	+0.066	+0.096	+0.230	−0.003	+0.223	+0.631	+0.746	71.24	−0.002560	11.7376	14.0268
5	....do	950	.....do	+1.270	+1.530	+1.524	+1.516	+1.676	+1.937	+1.489	+1.460	70.07	−0.002560	11.7381	14.1035
6	Bond	199	Wm. Bond & Son	+2.091	+2.137	+2.131	+2.159	+2.104	+1.794	+1.801	+2.103	62.63	−0.002800	14.0675	14.6188
7	....do	2007	Poole	+1.484	+1.780	+1.846	+1.944	+1.890	+2.187	+2.274	+2.210	82.96	−0.001970	13.9639	15 2295
8	....do	294	Wm. Bond & Son	+3.056	+3.101	+3.131	+3.337	+3.461	+2.794	+2.953	+3.603	148.14	+0.000488	12.6416	15.6000
9	....do	446	.....do	+0.556	+0.566	+0.524	+0.587	+0.497	+0.116	+0.096	+0.353	62.02	−0.002960	15 2296	15.7552
10	Negus	1293	T. S. & J. D. Negus	−0.801	−0.684	−0.547	−0.449	−0.610	−0.563	−0.654	−0.754	67.16	−0.001610	15.2231	16.2231
11	....do	1738	.....do	+0.127	+0.137	+0.381	+0.301	+0.283	+0.651	+0.417	+0.317	61.61	+0.000413	15.2854	16.3360
12	....do	1272	.....do	−1.194	−0.934	−0.869	−0.699	−0.824	−0.849	−1.261	−1.040	70.64	−0.003160	16.1396	16.3535
13	Bliss	1081	De Silva	+1.091	+1.280	+1.453	+1.587	+1.426	+1.330	+1.274	+1.389	69.13	−0.003560	16.0436	16.4036
14	Negus	1120	T. S. &. J. D. Negus	+0.163	+0.351	+0.417	+0.694	+0.461	+0.687	+0.917	+1.067	74.60	−0.002870	15.2999	16.8875
15	....do	725	.....do	+0.934	+0.887	+0.774	+1.516	+1.569	+1.473	+1.417	+1.853	76.81	−0.001730	10.2539	17.2764
16	.. do	1520	.....do	−0.190	−0.239	−0.316	−0.179	−0.239	−0.689	−0.746	−0.419	62.31	−0.002870	16.5434	17.5344
17	....do	1597	.....do	−6.766	−0.899	+0.654	−0.663	−0.610	−0.456	−0.476	−0.576	175.68	−0.000025	17.1351	18.0140
18	....do	1234	.....do	+0.556	+0.744	+0.703	+0.659	+0.604	+0.187	+0.131	+0.460	62.70	−0.001840	17.6416	18.6168
19	....do	1266	.....do	+0.306	+0.351	+0.631	+0.873	+0.640	+0.687	+0.703	+0.817	70.79	−0.003640	18.1556	19.2062
20	Bliss	2149	John Bliss & Co	+0.984	+1.351	+1.131	+1.409	+1.426	+1.330	+1 417	+1.710	66.81	−0.003400	16.6013	19.3238
21	Bond	397	Edwards & Hunter	+0.699	+0.851	+0.917	+1.016	+1.069	+0.830	+0.739	+0.889	70.75	−0.001420	17.9837	19.7393
22	... do	2507	Barraud	+1.377	+1.566	+1.566	+1.766	+1.640	+1.723	+1.703	+1.746	71.14	−0.003560	19.1066	19.9166
23	Negus	1195	T. S. & J. D. Negus	+0.163	+0.423	+0.596	+0.909	+0.640	+0.759	+0.631	+0.781	73.12	−0.003120	18.6204	20.5529
24	....do	718	.....do	+0.413	+0.423	+0.274	+0.337	+0.211	−0.384	−0.726	+0.031	63.71	−0.003750	22.0655	25.0861
25	... do	190	.....do	−0.194	+0.280	+0.631	+0.873	+0.747	+0.759	+0.596	+0.889	68.23	−0.002760	12.6471	26.9960
26	....do	1315	.....do	−1.087	−1.149	−0.761	−0.484	−0.503	−0.813	−0.833	−0.611	65.52	−0.004080	24.3334	27.0559
27	....do	991	.....do	−0.730	−0.470	−0.333	−0.270	−0.467	−0.384	−0.654	−0.647	70.05	−0.003840	26.0056	27.1081
28	Bond	4613	Thomas Adams	+1.270	+1.637	+1.667	+1.837	+1.533	+1.973	+1.346	+1.139	73.80	−0.001610	23.8611	28.1584
29	....do	293	Wm. Bond & Son	−0.480	−0.541	−0.583	−0.341	−0.467	−0.884	−0.976	−0.469	66.03	−0.003320	27.4882	28.8924
30	Negus	1684	T. S. & J. D. Negus	−2.104	−1.989	−1.959	−1.823	−1.987	−1.976	−1.959	−1.990	47.17	−0.000904	26.4067	29.1292
31	Bond	505	Wm. Bond & Son	−2.837	−3.077	−2.797	−2.341	−2.217	−2.349	−2.404	−2.076	20.76	+0.000409	28.2593	33.1434
32	Bliss	29480	Dent	−1.051	−0.756	−0.619	−0.720	−0.574	−0.527	−0.619	−0.469	−262.01	−0.000091	31.0014	34.2414

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33	Negus	1470	T. S. & J. D. Negus	+0.253	−0.631	−1.137	−0.966	−1.023	−1.083	−1.067	−0.883	35.94	−0.000611	26.5023	35.0579
34	do	1311	do	+0.877	+0.209	+0.131	+0.328	−0.039	−0.813	−0.511	−0.433	64.30	−0.003510	3.8357	35.1257
35	do	1519	do	−2.211	−1.774	−1.851	−1.821	−1.809	−2.119	−2.053	−1.861	66.29	−0.004520	33.8179	35.3185
36	do	1282	do	+1.668	+1.816	+1.917	+1.944	+1.854	+1.630	+1.774	+1.817	48.01	−0.005140	36.3529	37.0335
37	Bliss	464	Usher & Cole	+1.663	+2.244	+2.096	+2.123	+2.390	+2.009	+1.631	+1.746	70.95	−0.001450	34.2408	40.8714
38	Negus	1244	T. S. & J. D. Negus	−0.873	−0.613	−0.547	−0.234	−0.717	−0.241	+0.203	+0.103	71.75	−0.004030	38.3269	42.5294
39	Bond	694	De Silva	+0.806	+0.923	+0.989	+0.980	+0.961	+0.544	+0.453	+0.924	60.66	−0.003360	42.0131	44.3053
40	do	3276	Charles Frodsham	+2.377	+2.530	+2.669	+2.159	+2.069	+1.973	+1.846	+1.781	70.27	−0.005130	44.1522	48.0528
41	Negus	1750	T. S. & J. D. Negus	+1.020	+1.173	+1.346	+1.144	+1.319	+1.366	+1.310	+1.246	65.63	−0.002200	51.7023	53.6288
42	do	775	do	+0.806	+1.244	+1.417	+1.480	+1.354	+0.973	+0.953	+1.317	71.22	−0.005500	53.9735	55.4135
43	do	1059	do	+2.913	+2.780	+2.917	+2.587	+2.390	+2.116	+2.274	+1.996	61.03	−0.001770	55.0079	59.2433
44	Bliss	2101	Crisp	+0.163	+0.566	+0.631	+0.730	+0.569	+0.259	+0.274	+0.496	72.49	−0.001150	58.3188	65.4744
45	Negus	1267	T. S. & J. D. Negus	+2.377	+2.459	+2.631	+2.623	+2.461	+2.759	+2.953	+3.067	67.38	−0.005570	84.5719	90.4041
46	do	1268	do	−0.301	+0.137	+0.381	+0.587	−0.354	+0.366	+0.131	+0.210	67.69	−0.003520	82.9804	92.9850
47	do	1097	do	−2.873	−2.684	−2.690	−2.091	−2.217	−2.170	−2.297	−2.290	70.29	−0.001710	115.8976	119.4621
48	do	919	do	−2.980	−2.613	−2.654	−2.949	−3.003	−2.491	−2.404	−2.576	73.41	−0.004510	141.2156	143.0058
49	do	1226	do	.....	.....	.....	.....	.....	.....	.....	.....	71.28	−0.003640	32.2036	.....

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APPENDIX B.

[Report of Professor William Harkness, of the Transit of Venus Commission.]

U. S. NAVAL OBSERVATORY,
Washington, August 13, 1889.

SIR: I have the honor to submit the following report of the work done during the past year, under my supervision, for the Transit of Venus Commission:

Mr. A. S. Flint was the only assistant employed at the beginning of the year, and he left the service of the Commission on November 24, 1888, because of the exhaustion of the appropriation out of which his salary was paid. Since that date I have had no assistant.

The reduction of all the photographs taken with horizontal photoheliographs of about 40-feet focus, during the transit of Venus in December, 1882, is now complete, and if we put π for the solar parallax, and δA and δD, respectively, for the corrections to the right ascensions and declinations of Venus given by Hill's tables of that planet, it being assumed that Hansen's tables of the sun are correct, the results may be stated as follows:

From position-angles measured on 1,426 photographs:

$\pi = 8.772'' \pm 0.0496''$ $\quad \delta A = +2.724'' \pm 0.0811''$ $\quad \delta D = +1.447'' \pm 0.1343''$

From distances measured on 1,475 photographs:

$\pi = 8.847'' \pm 0.0122''$ $\quad \delta A = +2.893'' \pm 0.0430''$ $\quad \delta D = +1.246'' \pm 0.0241'$

Weighted mean from both position angles, and distances:

$\pi = 8.842'' \pm 0.0188''$ $\quad \delta A = +2.856'' \pm 0.0380''$ $\quad \delta D = +1.252'' \pm 0.0237''$

From the American Ephemeris for 1882, pp. 278 and 405, we have for the epoch 1882, December 6^d 5^h 00^m Greenwich mean time,

Apparent right ascension of sun,	253° 12′ 35.75″
Apparent declination of sun,	−22° 33′ 17.53″
Apparent obliquity of ecliptic,	23° 27′ 09.49″
Log. distance, sun to earth,	9.9934260
Log. distance, sun to Venus,	9.8576405
Inclination of orbit of Venus,	3° 23′ 36.32″
Constant of aberration,	20.4451″

From the photographs, the observed position of Venus for the epoch in question, is—

Apparent right ascension = 253° 12′ 35.75″ − 02′ 44.424″ + 02.856″
= 253° 09′ 54.182″ + $d\alpha\odot \pm 0.0380''$.
Apparent declination = −22° 33′ 17.53″ − 10′ 21.371″ + 01.252″
= −22° 43′ 37.649″ + $d\delta\odot \pm 0.0237''$.

And from these data we find:

Apparent geocentric longitude of sun,	254° 31′ 39.976″
Apparent geocentric latitude of sun,	− 0° 00′ 00.093″
Apparent geocentric longitude of Venus,	254° 30′ 23.235″ + $d\lambda\odot$
Apparent geocentric latitude of Venus,	− 0° 10′ 33.255″ + $d\beta\odot$
True geocentric longitude of sun,	254° 32′ 00.729″
True geocentric latitude of sun,	− 0° 00′ 00.093″
Heliocentric longitude of Venus,	74° 32′ 24.611″ + $d\lambda\odot$
Heliocentric latitude of Venus,	− 0° 03′ 51.791″ − $d\beta\odot$

Longitude of Venus in her orbit = 74° 32′ 17.74″ + $d\lambda\odot$ + 0.030 $d\beta\odot$
Longitude, ☊ = 75° 37′ 33.91″ + $d\lambda\odot$ − 16.868 $d\beta\odot$ − 0.321 di.

With $\pi = 8.842'' \pm 0.0118''$, and 3963.296 miles for the equatorial radius of the earth, which is General A. R. Clarke's value, the mean

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distance from the earth to the sun is 92,455,000 miles, with a probable error of only 123,400 miles.

The measurements of the eighty-six photographs taken at New Haven have not yet been finally discussed, and the reduction of the photographs taken during the transit of December, 1874, has never been completed. Furthermore, the contact observations made by our own parties in 1874 and 1882, and by nearly a hundred volunteer observers in 1882, yet remain unreduced. I need the services of an assistant in order to accomplish all this work with the rapidity which is desirable.

Thus far Congress has provided only for the printing of the observations of the transit of 1874; and, as these observations are now nearly all in type, I would respectfully call attention to the urgent need of some provision for the printing of the observations made in 1882. If such provision is deferred until after the manuscript is ready for the printer, much unnecessary delay will result.

Hitherto it has been customary to endeavor to determine the solar parallax as if it were an independent constant, and the result is a mass of discordant values, all of which are more or less affected by constant errors, and none of which commands anything like universal assent. But, in truth, the solar parallax is not an independent constant. On the contrary, it is entangled with the lunar parallax, the constants of precession and nutation, the parallactic inequality of the moon, the lunar inequality of the earth, the masses of the earth and moon, the ratio of the solar and lunar tides, the constant of aberration, the velocity of light and the light equation, and, according to the most elementary mathematical principles, it should be determined simultaneously with all these quantities. No other method affords anything like so much promise of eliminating the ever-present constant errors, and for that reason I took it up last fall, intending to prosecute it as a private investigation during my leisure time. The results attained were presented to the Philosophical Society of Washington on October 13, 1888, but since then, in connection with my official work, the paper has been greatly expanded and will be ready for publication in a few days. In accordance with your wishes it is to form part of the annual volume of this Observatory.

Very respectfully,

WILLIAM HARKNESS,
Professor of Mathematics, U. S. Navy,
Of Executive Committee of Transit of Venus Commission.

Capt. R. L. PHYTHIAN, U. S. Navy,
Superintendent of Naval Observatory,
President of Transit of Venus Commission.

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[REPORT OF THE SECRETARY OF THE NAVY, 1890. pp. 92–103.]

REPORT

OF

THE SUPERINTENDENT

OF THE

U. S. NAVAL OBSERVATORY

FOR THE

YEAR ENDING 1890 JUNE 30

WASHINGTON
GOVERNMENT PRINTING OFFICE
1890

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REPORT

OF THE

SUPERINTENDENT OF THE U. S. NAVAL OBSERVATORY

WASHINGTON, 1890

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REPORT OF SUPERINTENDENT OF NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, September 9, 1890.

SIR: In compliance with the Bureau's instructions, dated September 1, 1890 (No. 3975), I have the honor to submit a report of the operations of the Naval Observatory during the year ending June 30, 1890.

By order of the Honorable the Secretary of the Navy, I reported to Capt. R. L. Phythian, U. S. Navy, on June 28, 1890, for duty as Superintendent of the U. S. Naval Observatory, as his relief.

The following is a brief statement of the work performed.

I. THE 26-INCH EQUATORIAL.

(Prof. Asaph Hall, U. S. Navy, in charge.)

Observations of a list of double stars were continued, as in preceding years. These stars are mostly those that have large orbital motions, and observations therefore are of value in determining their orbits. Some other of the older stars of this class, which have not rapid motions, have also been observed, in order to connect our observations with those made elsewhere, and thus to furnish a means of reducing the observations to a common standard. A few new double stars were observed, but no attempt has ever been made here to discover new doubles, of which many of the fainter magnitudes could be found. The new stars have generally been observed at the request of other astronomers.

As the last opposition of Saturn was very favorable for determining the orbit of Iapetus, the outer satellite, a full series of observations was made. The conjunctions of some of the inner satellites of Saturn with the minor axis of the Ring were observed.

Observations of the satellites of Mars were made during the opposi-

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tion of this planet, but owing to the low position of Mars it was found practicable to record but a limited number of observations.

Ensign H. S. Chase, U. S. Navy, assistant to Professor Hall, has been employed in revising and reducing observations, in comparing observations of 1889 of Iapetus with the tables, and in computing an orbit of one of the recent comets.

The reduction of observations of double stars from 1880 to 1891 is is well advanced. Observations of Iapetus should be reduced and discussed; also observations of the satellite of Neptune. One computer for one year is required to bring this work up to date.

II. THE TRANSIT CIRCLE.

(Prof. J. R. Eastman, U. S. Navy, in charge.)

The transit circle has been employed in observations of the sun, moon, major and minor planets, and such stars as were necessary for clock and instrumental corrections. Observations have been continued on the list of stars for the U. S. Coast and Geodetic Survey.

The assistants on the transit-circle work were:

Assistant Astronomer A. N. Skinner, Assistant Astronomer A. Hall, jr. (since August 1, 1889), Computer William M. Brown, Computer George A. Hill (since November 15, 1889), Computer Charles S. McCoy (since December 1, 1889), Computer A. S. Flint (until his resignation November 1, 1889).

There were made 1,920 observations with the transit circle. Of this number, 47 were of the sun, 44 of the moon, 75 of the major planets, 16 of the minor planets, and 7 of Comet *a* 1890 (Brooks).

At the request of Carleton College Observatory, Northfield, Minn., clock signals were exchanged with that Observatory on October 16, 17, and November 5, to determine its longitude.

The continued reduction of the observing force has prevented any work on the German Zone.

The transit-circle work for 1885 is in print; the reductions for 1886 are nearly finished, and the apparent-place reductions for 1887 are more than half completed, while those for the years 1888, 1889, and 1890 have not been commenced.

From the foregoing it will be seen that the publications of the Observatory are in arrears five years, and in order to reduce those observations and complete the work on hand for publication two additional computers are required.

By recommendation of a board of survey it is proposed to dismount this transit circle about January 1, 1891, for extensive repairs and alterations, at an estimated cost of $3,000, which will prevent its use for about five months.

III. THE 9.6-INCH EQUATORIAL.

(Prof. Edgar Frisby, U. S. Navy, in charge.)

This instrument was used for observations of comets, minor planets, and occultations of stars by the moon. Eleven observations of minor planets and forty-eight observations of comets were taken, and three occultations observed. The results of the observations of comets have been published in Gould's Astronomical Journal The work is all reduced to date and can be prepared for the printer in a few days.

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Two evenings in every week were set for the accommodation of visitors for a view of the heavens through this telescope, and 1,735 permits were issued, exclusive of those issued by the Bureau.

IV. THE MERIDIAN TRANSIT INSTRUMENT.

(Lieut. B. W. Hodges, U. S. Navy, in charge.)

Observations have been made with this instrument on every clear night for corrections to the standard and other clocks. The clocks have performed well. The telescope continued in good order, with a brief interruption caused by the breaking of the threads of the diaphragm; these were immediately replaced, and in addition to the usual work, repeated observations of α Ursæ Minoris and other circumpolar stars were taken and computations made until new equatorial intervals were established. This work had not previously been done since December, 1883. The machinery has generally been in good working order. Some slight repairs and alterations, however, are deemed necessary.

V. VARIABLE-STAR OBSERVATIONS.

(Assistant Astronomer H. M. Paul, in charge.)

Owing to Mr. Paul's additional duties as librarian, the time available for work upon variable stars has been quite limited, and the observations have been confined mostly to the new variable of short period discovered by him in the constellation *Antlia*, as referred to in the last annual report. This star has been observed on thirty-two nights during the last opposition, and twenty-one of these give determinations of the times of minimum phase with a greater or less degree of accuracy.

A preliminary announcement of the discovery, based upon the observations of the first opposition only, comparatively few in number, left the period doubtful between two possible values of about $0^d.48$ and $0^d.324$; but the reductions have now progressed far enough to show that the period deduced by Mr. Chandler in the *Astronomical Journal*, IX: 190, viz: $7^h\ 46^m\ 48^s.0$, will be changed by only a very small fraction of a second, and the results will be soon be published in the *Journal*.

Mr. Chandler has assigned a letter to this star, and it will hereafter be known as *S Antliæ*. It is remarkable as having by far the shortest period of any yet discovered, that of the next shortest, *U Ophiuchi*, being $20^h\ 7^m\ 41^s.6$.

VI. CHRONOMETERS AND TIME SERVICE.

(Lieut. Hiero Taylor, U. S. Navy, in charge.)

Since the general adoption of standard time the Observatory has been dropping time balls at Newport, Wood's Holl, New York, Philadelphia, Baltimore, Fort Monroe, Savannah, and New Orleans at noon, 75th meridian time. This is done through the co-operation of the Western Union Telegraph Company, which each day suspends its business for the time used in sending the signals and allows the Observatory the free use of its lines. The signals, which begin at $11^h.\ 56^m.\ 45^s.$ a. m., 75th meridian time, are sent automatically every second, omitting the 29th, 55th, 56th, 57th, 58th, and 59th, until $11^h.\ 59^m.\ 50^s.$, after which there are no more signals until noon when there is a long signal, made long purposely to insure the acting of the electro-magnets

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which are used on the ball-detaching apparatus. Operating over Government lines, the Observatory also drops a time-ball in Washington and sets to correct time several hundred clocks which have been placed in the Government offices. These are ordinary clocks with the addition of a simple mechanical device operated by electricity, by which they may be corrected when they have gone astray.

The Observatory has been greatly hampered in this branch of its work by lack of funds. In view of the great importance of the ball-signals to mariners and others, there should be a system of return signals by which the errors in the dropping of the various time balls may be measured and given to the public. The system of corrected clocks might be advantageously extended to all the Government offices, insuring accurate and uniform time for the transaction of Government business. An appropriation is greatly needed for these purposes.

The fact that the Government has never formally adopted a standard of time for the transaction of business has led to vexatious complications in land entries in territories in various ways and channels too well known to particularize. A standard of time is quite as important as one of weight or of measure, and the time distributed from the Observatory ought to be legalized by an act of Congress.

Forty-seven chronometers have been issued to ships and shore stations and thirty-three have been turned in. Thirty-five have been subjected to the usual tests of the temperature-room, and their tests in the chronometer-room are very nearly completed. The computations in connection with this work are nearly completed and the results of the trial will be submitted in a supplementary report. (See Appendix B.)

The following table shows the number and disposition of the chronometers belonging to the Navy:

Disposition.	Number.	Disposition.	Number.
At the Observatory	*149	Issued to ships	156
In use (at the Observatory)	19	Issued to shore stations	37
Ready for issue (at the Observatory)	35	At navy-yard, Mare Island	40
Under trial (at the Observatory)	†34		
Awaiting trial (at the Observatory)	6	Total	497
Being repaired	21		

*Of these 149, 148 with an estimated value of $42,365, were surveyed and condemned.
†These 34 chronometers will be ready for issue in two weeks.

In response to a circular letter from the bureau to watchmakers and dealers, 138 watches were submitted for a competitive trial. Of these the best twenty were purchased for use as comparing watches.

Lieutenant Taylor was assisted by Ensign B. C. Decker from August 1, 1889, until the latter's detachment January 6, 1890; Ensign T. J. Loomis from January 22 to April 8, 1890, and Ensign H. H. Whittlesey since February 25, 1890.

VII. INSPECTION OF INSTRUMENTS.

(Lieut. Walton Goodwin, U. S. Navy, in charge.)

Lieutenant Goodwin was detailed for this duty October 5, 1889, succeeding Ensign A. B. Clements, who was detached from the Observatory September 16, 1889.

There have been received at the Observatory, as the depot of nautical

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instruments for the Navy, many instruments of various kinds, the accumulation of years from the different navy-yards. The condition of a large majority of these instruments was such as to render them unfit for repairs or further issue. These, together with many old, worn-out, and useless chronometers in store here, the whole representing an invoice value of over $50,000, have been surveyed and recommended to be condemned and sold. Since the survey was held, other instruments have been received from various sources, the condition of many of which being such as to warrant a survey and condemnation.

Forty-seven sextants and twenty-three octants have been repaired. The eighty-five sextants and sixty-eight octants remaining for issue at the end of the fiscal year are, with the exception of five, old instruments that have been frequently repaired and must fail to give the satisfactory results of new and modern instruments.

It is recommended that a number of new sextants be purchased, so that vessels going in commission may be supplied with at least one new and superior instrument, fitted with the necessary glasses for day and night work; the repaired sextants on hand to be issued as ordinary ones, and no more octants to be purchased or repaired, and none of the atter to be issued after the present supply shall be exhausted.

Twenty-five spy-glasses and fifty binoculars represent the only new instruments that have been received for inspection and accepted. They are of high power and superior manufacture.

Twenty five mercurial barometers are undergoing repairs, on the completion of which they will be delivered to the New York navy-yard for inspection. The delicate nature of these instruments and the great risk incurred in their transportation suggest the expediency of keeping a supply on hand at each of the navy-yards, where they could be conveniently compared with the standard barometer and be subjected to the minimum risk of transportation.

Nautical instruments of various kinds, after careful inspection, have been supplied from the Observatory to the new ships that have been put in commission and to other vessels where deficiencies rendered them necessary.

The Bureau's attention is invited to the system it has inaugurated of having the nautical instruments for naval use practically under its immediate supervision at the Naval Observatory. Old and useless articles that have been carried on the books at the various navy-yards for years have been eliminated, and it can hardly be doubted that under the present careful manner of inspection by experts specially detailed for this work, commanding and navigating officers can fail to be satisfied with the efficiency of these instruments of precision, so essential to successful navigation.

VIII. MAGNETIC INSTRUMENTS.

(Ensign J. A. Hoogewerff, U. S. Navy, in charge.)

Ensign C. C. Marsh, U. S. Navy, was in charge of this department until January 6, 1890, though absent in Europe on duty in connection with magnetic work from July 3 to November 15, 1889, during which interval the duties of the office were performed by Ensign Hoogewerff, who finally succeeded Mr. Marsh on January 6, 1890. Ensign W. B. Hoggatt, U. S. Navy, was assigned to duty as assistant on January 11, 1890.

The self-recording megnetographs have been in operation contin-

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uously, with the exception of a short time in January, when they were examined, cleaned, and, when necessary, readjusted. The scale values in terms of force and the temperature corrections of the horizontal and vertical force instruments have been determined frequently during the year. Observations for absolute declination have been made twice each day, and the value of the base lines of the declination traces deduced from them.

Observations of the horizontal intensity of the earth's magnetic force have been made on four days of each month throughout the year.

The magnetic inclination (dip) has been determined at least eight times each month, using three needles in rotation.

The results of the absolute observations of declination, horizontal intensity, and dip have been reduced and combined with the continuous photographic records, and the declination, horizontal force, and vertical force tabulated for each hour of the year.

Drawings of the composite curves of declination for each month, and comparisons of the declination traces on disturbed days at Washington, Los Angeles, and Toronto have been made, and copies sent to magnetic observatories and persons interested in magnetic work. The results of the work to January 1, 1890, together with plates of the drawings made, have been prepared for printing and will soon be published.

The superintendent of the U. S. Coast and Geodetic Survey, Professor Carpmael, director of the Meteorological Service of Canada, and the director of the Imperial Russian Magnetic Observatory have shown great interest in the comparison of the declination traces taken here and at their observatories, and have kindly furnished copies of their traces for disturbed days in 1889; and the drawings of these comparisons will be reproduced in the volume soon to be published.

Two seismoscopes, connected with clocks kept rated, and a seismograph have been kept in working order throughout the year, but no earthquake shock of sensible magnitude has been experienced.

The magnetic instruments are in good order, but they are old and not equal in accuracy and sensitiveness to the instruments that are now made.

The number of permanent magnetic observatories in the world are:

Country.	No.	Country.	No.
England	3	Switzerland	1
France	6	China	1
Germany	2	Japan	1
Austria	2	Philippine Islands	1
Russia	1	Java	1
Belgium	1	Australia	1
Holland	1	South Africa	1
Denmark	1	Madagascar	1
Spain	1	Mauritius	1
Portugal	1	Brazil	1
Argentine Republic	2	Canada	1
Chili	1	United States	1

It will be seen from this list that nearly every nation of any importance maintains at least one such observatory, which, in most cases, is fitted up with the most improved modern instruments.

The United States has but one, and in order to do her part for the promotion of science, and particularly of a science, so intimately connected with navigation, this observatory, established and maintained by our Navy Department, should be fitted with the best instruments,

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and equipped so that its contributions to science, particularly to the science of navigation, should be equal to those of any such observatory in the world.

The services of a laborer to keep the magnetic buildings in order, attend to the arrangements for securing an even temperature in the magnetograph room, and to read and record temperatures, are urgently required. A salary of $720 per annum would secure the services of a man who, in addition to these duties, could be trained to develop the photographs, make prints, and do other work which at present takes up much of the time of the officers in charge that could then be more profitably employed.

IX. THE LIBRARY.

(Assistant Astronomer Paul in charge.)

The contents of the library on June 30, 1890, as shown by the accession book, were 12,643 volumes and 2,915 pamphlets, the accessions during the year having been 630 in number, 417 volumes and 213 pamphlets. Of these, 403 were received as exchanges and 227 were purchased.

The number of accessions would have been considerably increased by bound volumes of periodicals if any binding had been done. But the binding for the library has of late fallen behind, first, on account of the exhaustion of the Department's fund for printing and binding during a large part of the year, and, secondly, from the lack of sufficient assistance promptly to prepare volumes for the bindery.

The third edition of Yarnall's Catalogue of Stars, prepared by Professor Frisby, was received from the printer and distributed to our entire exchange list. As the stars have been renumbered in this edition, and hence the numbers need to be distinguished from those of the first two editions, it is suggested that "Yarnall [F]" be used as a brief and distinctive reference to this third edition of the catalogue.

The following publications have also been received from the printer:

1. The Annual Report of the Superintendent for 1889.
2. The Annual Volume for 1884.
3. 1885, Appendix II.—Saturn and its ring, by Prof. Asaph Hall.
4. 1885, Appendix I.—International Astrophotographic Congress, by Lieut. A. G. Winterhalter.

The following are in press:

1. The Annual Volume for 1885.
2. 1885, Appendix III.—The Solar Parallax and its Related Constants, by Prof. William Harkness.

These are nearly completed, and it is expected that they will be distributed before January 1, 1891.

Through a wide system of exchanges for our own publications, and a careful purchase of such works as could not be obtained in exchange (both continued for many years), the library of the Naval Observatory has now grown to be by far the most complete and valuable library of reference in astronomy to be found this side of Europe, and it is fairly equipped in the literature of mathematics, physics, chemistry, geodesy, meteorology, engineering, and geography.

In order to secure the proper care and administration of a valuable and rapidly-growing library of this character it has been found necessary to take one of the assistant astronomers from his proper astronomical duties to give his whole time as librarian.

As at present arranged, all the library work, including the examination and cataloguing of all new accessions, the careful preparation of the

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same for the bindery, the daily registration of periodicals and books received, the examination of book-catalogues and ordering of books, the careful supervision of the distribution of the observatory publications and filing of receipts for the same, the registration and occasional inventory of books taken out of the library, and the library correspondence devolves upon the librarian with such limited assistance as he can obtain from one messenger when the latter is not elsewhere engaged.

The librarian finds that he can not, even with eight or nine hours' work daily, keep the current work of the library up to date. No inventory of the contents of the library has been taken for at least twelve years, and there is no shelf list or other other reliable catalogue by which to check the contents, even if time and assistance were available to do it. With the removal of the library to the new observatory it will be necessary to reclassify and recatalogue the library entirely anew, and a large increase of library assistance will be indispensable. If a part of this were available at once, very much of the necessary preliminary work could be done to better advantage here before removal.

By reason of the foregoing, and especially in view of the imperative need of more help to keep up the current work as it is, it is hoped that the estimate submitted for an assistant librarian and a cataloguer will receive the favorable consideration of Congress.

PERSONNEL.

Out of the corps of twelve professors of mathematics in the Navy, there are now only six who are on duty as astronomers; one of the ablest of these will be retired shortly, leaving but five for service at the Observatory and Nautical Almanac Office. In contrast with this there were in 1876, and for several years about that time, six professors of mathematics, well known as astronomers, engaged in active work at the Observatory alone. The issuing of the annual volumes of the Observatory has been for years falling farther and farther behind, until now publication is five years behind the observations, and the amount of work done has been growing less and less. Important improvements in instruments and in methods of observation, as well as new and equally important lines of research, many of which are actively pushed forward at the principal Government observatories, have here been entirely neglected on account of the lack of practical astronomers to make independent observations and to carry on special investigations in conjunction with other observatories. In this connection, it is much to be regretted that from the cause just mentioned this observatory was unable to perform its part in observing the positions of the stars in the zone assigned to complete a chart of the heavens.

From the organization of this naval institution, its personnel must be drawn principally from officers of the Navy; and it is necessary to appoint some professors of mathematics, astronomers of known experience, as it is mainly to this corps that the Observatory has to look for aid to keep up its astronomical reputation.

It is scarcely necessary to add that, when the new Naval Observatory is completed and equipped, the force of astronomers and assistant astronomers will have to be materially increased if the observatory is to be worthy of our great and progressive country.

The reductions and computations of the transit of Venus observations of 1874 and 1882 are in charge of Prof. William Harkness, U. S. Navy, who is attached to the Observatory on this special duty. His report is hereto appended.

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NEW NAVAL OBSERVATORY.

The work on the new Naval Observatory is slowly approaching completion, but it can not be finished before the spring of 1891. The principal cause for the delay in the construction of the buildings is attributed to the want of cement of a quality to pass the prescribed tests, and procrastination in the delivery of marbl .

The condition of the work to date is as follows:

Main building.—Under contract, the walls are nearly finished, the iron roofing ready to put in place, and the building should be under cover by November. The small equatorial pier is built to a level with the first floor; steam-heating work is partially done; cold-air ducts are commenced. Small equatorial stairs, plumber, joiner, carpenter, and plasterers' work, etc., to finish the interior of building, are yet to be done.

Great equatorial.—Walls, marble and brick, are practically completed, and the roof partially finished. This work has been delayed for the want of a few pieces of marble, which are now arriving, but can be completed in ten days. The dome and basement pier have been contracted for.

Clock and observers' rooms are under cover and nearly completed; the erection of the basement clock-piers has been contracted for.

Three transit-circle rooms.—Floor beams are being laid, and the iron-work for their respective superstructures is ready, with the exception of the shutters, which are yet to be ordered. The basement piers have been contracted for, and this work should be done in three months.

Prime-vertical.—This building has not yet been commenced, as the ground assigned to it is occupied by the old mansion, but this is now being torn down and the erection of this small prime-vertical building can easily be completed in three months.

Boiler-house.—Completed except a few minor items.

Drain pipes, soil pipes, and cesspool are not completed.

Estimates.—As it is proposed to occupy the new observatory during the summer of 1891, estimates will be submitted for new instruments, for moving and mounting old instruments, for water supply, lighting, laying out grounds, for furniture, officers' quarters, etc., and for necessary expenses to manage this new establishment.

Very respectfully,

F. V. McNAIR,
Captain U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF EQUIPMENT.

APPENDIX A.

[Report of Prof. William Harkness, U. S. Navy, of the Transit of Venus Commission.]

NAVAL OBSERVATORY,
Washington, July 15, 1890.

SIR: I have the honor to report that during the year ending June 30, 1890, I had no assistants, and nearly all my time was devoted to investigations and computations connected with my work on the solar parallax and its related constants.

As is well known, there exists a vast mass of astronomical, geodetic, gravitational, and tidal observations which have hitherto been discussed

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piece-meal, and have therefore yielded only isolated results. My object has been to deal with these observations as a whole, and to derive from them a homogeneous system of constants satisfying all the conditions imposed by our present theoretical knowledge. For that purpose recourse was had to the method of least squares, and a suitable system of simultaneous conditional equations was formed. The constants involved in these equations were the size of the earth, the lengths of the seconds pendulum, the sidereal month and the sidereal year, the ratio of the mean motions of the earth and moon, the eccentricities of the orbits of the earth and moon, the inclination of the moon's orbit, the rate of regression of its node, and certain co-efficients occurring in the lunar theory, and the first step was to ascertain the best values of these quantities. The observed quantities to be corrected by the least-square adjustment were the solar and lunar parallaxes, the constants of precession and nutation, the parallactic inequality of the moon's motion, the lunar inequality of the earth's motion, the constant of aberration, the light equation, the velocity of light, the flattening of the earth, the masses of the earth and moon, and indirectly, the masses of Mercury and Venus. In order to obtain proper values of these quantities for use in the conditional equations it was necessary to collect and discuss all the available astronomical, geodetic, gravitational, and tidal data; and, as this discussion included a special investigation of the masses of Mercury and Venus, the labor involved proved very great. Some unexpected delays have occurred, but the work is now so far advanced that 111 pages of it are in type, and it is believed that the entire paper will appear in the forthcoming Observatory volume for the year 1885.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics U. S. Navy,
Of Executive Committee of Transit of Venus Commission.

The SUPERINTENDENT OF THE NAVAL OBSERVATORY.

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APPENDIX B.—*Results of tests of repaired chronometers at*

Time, 1890		Feb. 5 to Feb. 12.	Feb. 13 to Feb. 20.	Feb. 21 to Feb. 28.	Mar. 1 to Mar. 8.	Mar. 9 to Mar. 16.	Mar. 17 to Mar. 24.	Mar. 26 to Apr. 2.	Apr. 4 to Apr. 11.	Apr. 13 to Apr. 20.	Apr. 21 to Apr. 28.
Temperature, Fahrenheit		51.51	58.98	68.99	79.37	89.22	79.39	69.37	58.92	51.49	66.89
Relative humidity, per cent.		60.3	67.2	72.4	61.8	66.0	60.0	53.2	59.4	65.0	66.3
Makers.	*Nos.*										
T. S. & J. D. Negus	1657	—0.203	+0.063	+0.217	+0.043	—0.111	—0.169	—0.416	—0.279	—0.124	+0.019
Wm. Bond & Son	273	—0.489	—0.116	—0.033	—0.529	—1.290	—0.526	—0.344	—0.350	—0.374	—0.410
Wm. Bond & Son	295	+0.833	+1.599	+1.789	+1.543	+0.424	+1.439	+1.584	+1.741	+1.019	+2.090
T. S. & J. D. Negus	589	+0.261	+0.956	+1.217	+1.043	+0.174	+1.117	+1.191	+1.043	+0.269	+1.661
T. S. & J. D. Negus	1615	+0.583	+0.706	+1.039	+0.757	+0.317	+0.403	+0.334	+0.400	+0.554	+0.554
Wm. Bond & Son	514	+0.797	+1.206	+1.003	+0.471	—0.183	+0.653	+0.941	+1.257	+1.161	+1.590
T. S. & J. D. Negus	1745	—0.453	+0.349	+0.503	+0.186	—0.933	—0.026	+0.227	+0.079	—0.839	+0.269
Do	1113	—0.739	—0.116	—0.283	—0.636	—1.826	—0.883	—0.844	—0.350	—0.910	—0.053
Do	1347	—0.560	—0.009	+0.181	—0.136	—1.469	—0.383	—0.059	—0.421	—1.124	—0.017
Do	1229	—0.453	—0.080	—0.461	—0.564	—1.790	—0.383	+0.191	—0.029	—0.767	+0.019
Do	1094	—0.881	+0.170	+0.646	+0.293	—0.397	—0.026	—0.166	—0.350	—1.017	+0.233
Do	1194	+0.476	+1.134	+1.646	+1.471	+0.139	+1.189	+1.049	+1.364	+0.590	+1.554
Do	772	—0.953	—0.116	+0.289	—0.314	—1.361	—0.597	—0.539	—0.636	—1.017	—0.196
Do	1299	—0.560	+0.277	+0.539	+0.114	—1.111	—0.276	+0.120	—0.243	—0.981	+0.054
Do	1641	—0.881	—0.366	—0.283	—0.836	—1.286	—0.811	—0.237	—0.564	—0.910	—0.267
Do	1145	—1.560	—0.187	—0.104	+0.221	—0.754	—0.026	+0.513	+0.150	—1.124	+0.340
Wm. Bond & Son	243	—0.989	—0.009	+0.539	—0.064	—0.576	+0.224	—0.023	—0.457	—1.231	+0.269
Barraud	2594	—0.203	+0.206	+0.431	—0.207	—1.469	—0.704	—0.273	—0.314	—0.660	—0.124
T. S. & J. D. Negus	1304	+0.083	+0.777	+0.824	—0.136	—1.111	+0.026	+0.227	+0.257	+0.054	+0.519
Penlington	1741	+1.476	+1.563	+1.181	—0.064	—1.433	—0.097	+0.906	+1.900	+1.590	+1.376
T. S. & J. D. Negus	700	—0.169	+0.599	+0.253	+0.007	—0.790	+0.117	+1.129	+0.543	—0.196	+0.947
Do	1595	—0.774	—0.099	+0.396	—0.314	—1.397	—0.597	—0.023	—0.100	—1.160	+0.054
Do	1189	—1.174	—0.759	—0.319	—0.921	—1.933	—1.419	—0.987	—1.064	—1.589	—0.553
John Bliss & Co	2484	—2.417	—1.473	—0.926	—1.814	—2.826	—2.169	—2.023	—1.921	—2.124	—1.339
T. S. & J. D. Negus	1327	—1.810	—1.009	—0.676	—0.743	—1.254	—0.061	+0.191	—0.957	—2.017	—0.910
Do	1281	—1.631	—0.080	—0.390	—0.814	—2.076	—0.954	—0.416	—0.529	—1.910	—0.410
Wm. Bond & Son	510	+2.797	+3.063	+2.717	+2.114	+0.996	+2.439	+3.620	+3.971	+3.554	+4.019
Jas. Munroe	266	+1.297	+1.041	+0.717	—0.467	+0.710	—0.204	+0.406	+0.936	+0.840	+0.590
T. S. & J. D. Negus	1088	—0.881	—0.009	+0.146	—0.029	—0.540	+0.546	+0.406	+0.007	—1.803	+0.911
Do	599	+0.024	+0.813	+0.753	—0.064	—1.540	—1.097	—0.701	+0.064	—0.267	+0.447
Wm. Bond & Son	307	+0.333	+0.884	—0.069	—1.243	—2.183	—0.633	+0.834	+0.971	+0.626	+1.376
T. S. & J. D. Negus	1449	+0.369	+0.813	+0.681	—0.064	—1.504	—0.883	—0.559	—0.850	—1.339	—0.124
Do	1232	—1.831	—1.080	—0.033	—0.029	—2.040	—0.633	—0.201	—0.921	—1.410	—0.910
Do	997	+1.119	+1.080	+1.539	+0.864	—0.290	+0.903	+2.049	+1.649	+0.376	+2.626
Bliss & Creighton	2143	—3.274	—2.830	—1.604	—1.957	—2.326	—1.990	—2.416	—2.529	—3.339	—1.910

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the Naval Observatory—February 5 to July 14, 1890.

Apr. 28 to May 5.	May 5 to May 12.	May 12 to May 19.	May 19 to May 26.	May 26 to June 2.	June 2 to June 9.	June 9 to June 16.	June 16 to June 23.	June 23 to June 30.	June 30 to July 7.	July 7 to July 14.	Temperature of compensation.	Temperature of constant.	Trial number.	Relative number.
69.21	68.68	72.14	72.19	74.13	80.17	78.56	78.28	82.32	81.43	80.91				
67.4	68.0	73.0	70.0	65.0	68.0	71.8	71.1	67.5	71.2	64.7				
−0.107	−0.110	−0.174	−0.271	−0.411	−0.300	−0.471	−0.471	−0.354	−0.384	−0.670	60. 67	+0. 00013	6. 406	1
−0.321	−0.360	−0.396	−0.379	−0.447	−0.657	−0.686	−0.614	−0.890	−0.884	−0.884	65. 26	−0. 00184	6. 589	2
+2.107	+2.426	+2.433	+2.479	+2.374	+2.200	+1.957	+2.100	+1.896	+1.973	+1.937	68. 51	−0. 00166	6. 740	3
+1.714	+1.747	+1.754	+1.800	+1.874	+1.450	+1.600	+1.493	+1.289	+1.401	+1.437	70. 43	−0. 00157	6. 761	4
+0.643	+0.783	+0.754	+0.943	+0.910	+0.986	+0.921	+0.993	+1.003	+1.116	+0.830	69. 74	−0. 00114	9. 080	5
+1.750	+1.890	+1.933	+1.907	+1.981	+1.843	+1.814	+1.921	+1.753	+1.794	+1.759	46. 68	−0. 00073	9. 564	6
+0.107	+0.140	+0.004	+0.014	−0.019	−0.300	−0.329	−0.257	−0.533	−0.456	−0.527	67. 61	−0. 00208	10. 160	7
−0.107	−0.110	−0.210	−0.200	−0.447	−0.943	−0.971	−0.936	−1.319	−1.241	−1.349	61. 83	−0. 00175	11. 400	8
+0.107	+0.104	+0.004	−0.129	−0.269	−0.586	−0.471	−0.114	−0.461	−0.670	−0.670	68. 78	−0. 00286	13. 058	9
+0.071	+0.033	−0.210	−0.236	−0.483	−0.693	−0.579	−0.543	−0.961	−0.813	−0.813	60. 91	−0. 00124	13. 737	10
+0.429	+0.497	+0.576	+0 657	+0.696	+0.629	+0.564	+0.564	+0.431	+0.509	+0.474	71. 77	−0. 00209	15. 135	11
+1.571	+1.711	+1.504	+1.443	+1.410	+1.164	+1.136	+0.957	+0.646	+0.759	+0.830	72. 77	−0. 00055	15. 874	12
0.000	+0.104	−0.067	−0.129	−0.197	−0.443	−0.471	−0.436	−0.783	−0.741	−0.884	68. 44	−0. 00269	16. 361	13
0.000	−0.039	+0.040	+0.086	−0.054	−0.336	−0.364	−0.329	−0.604	−0.527	−0.599	68. 47	−0. 00346	17. 746	14
−0.429	−0.360	−0.460	−0.379	−0.519	−0.979	−0.936	−0.829	−1.247	−1.099	−1.170	66. 70	−0. 00380	18. 254	15
+0 536	+0.426	+0.754	+0.621	+0.481	+0.736	+0.707	+0.671	+0.467	+0.616	+0.437	70. 95	−0. 00157	18. 475	16
+0.536	+0.497	+0.576	+0.550	+0.553	+0.450	+0.350	+0.457	+0.324	+0.616	+0.116	71. 55	−0. 00320	19. 729	17
−0.071	+0.211	+ 0.183	+0.264	+0.196	−0.300	−0.221	−0.150	−0.569	−0.599	−0.491	66. 10	−0. 00319	21. 823	18
+0.679	+0.747	+0.933	+1.050	+0.910	+ 0.129	+0.279	+0.279	−0.033	+0.187	+0.259	64. 20	−0. 00290	22. 634	19
+1.143	+0.961	+0.826	+0.443	+0.267	−0.229	−0.221	−0.186	−0.604	−0.670	−0.706	48. 03	−0. 00210	23. 062	20
+0.857	+0.890	+0.647	+0.693	+0.410	+0.307	+0.314	+0 350	−0.033	+0.259	+0.223	65. 65	−0. 00354	23. 624	21
+0.000	+0.104	+0.004	+0.086	−0.233	−0.657	+0.650	+0.614	−1.176	−0.777	−1.027	66. 35	−0. 00398	23. 986	22
−0.036	−0.574	−0.353	−0.450	−0.447	−0.586	−0.614	−0.614	−0.711	−0.777	−0.777	67. 46	−0. 00371	25. 183	23
−1.429	−1.360	−1.353	−0.986	−1.126	−1.264	−1.293	−1.114	−1.319	−1.170	−1.170	67. 14	−0. 00354	28. 324	24
−0.250	−0.181	−0.103	−0.036	−0.126	−0.407	−0.257	−0.257	−0.711	−0.527	−0.527	72. 46	−0. 00131	34. 394	25
+0.107	+0.176	+0.397	+0.586	+0.624	−0 264	−0.900	−1.007	−1.319	−1.170	−1.313	61. 43	−0. 00183	34. 748	26
+3.393	+3.283	+2.826	+2.514	+2.589	+1.807	+1.743	+1.600	+1.324	+1.544	+1.544	57. 53	−0. 00261	36. 741	27
+0.357	+0.390	+0.254	+0.264	+0.017	−0.264	−0.507	−0.543	−0.461	−0.599	−0.491	49. 38	−0. 00175	39. 774	28
+0.679	+0.926	+1.147	+1.407	+1.624	+1.807	+0.850	+0.100	+1.146	−0.206	+0.044	73. 65	−0. 00141	40. 667	29
+0.607	+0.711	+0.754	+0.800	+0.731	+0.593	+0.600	+0.636	+0.360	+0.473	+0.259	50. 38	−0. 00124	42. 084	30
+0.893	+0.854	+0.826	+0.943	+0.589	+0.093	+0.136	+0.136	−0.140	+0.151	+0.187	56. 91	−0. 00372	42. 148	31
−0.107	−0.181	−0.281	−0.343	−0.376	−0.728	−0.900	−0.829	−1.140	−0.956	−0.991	65. 38	−0. 00293	54. 521	32
−1.321	−1.789	−2.246	−2.343	−2.197	−1.514	−1.043	−0.543	−1.533	−1.420	−1.491	72. 28	−0. 00525	55. 814	33
+3.107	+3.176	+3.607	+3.443	+1.267	+0.986	+0.957	+0.814	+0.753	+0.651	+2.937	63. 08	−0. 00399	80. 106	34
−2.179	−2.324	−2.067	−1.986	−2.126	−2.657	−1.471	−1.543	−1.354	−0.849	.....	74. 86	−0. 00303	.....	...

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[REPORT OF THE SECRETARY OF THE NAVY, 1891. pp. 122-131.]

REPORT

OF

THE SUPERINTENDENT

OF THE

U. S. NAVAL OBSERVATORY

FOR THE

YEAR ENDING 1891 JUNE 30

WASHINGTON
GOVERNMENT PRINTING OFFICE
1891

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REPORT

OF THE

SUPERINTENDENT OF THE U. S. NAVAL OBSERVATORY

WASHINGTON, 1891

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ANNUAL REPORT OF THE SUPERINTENDENT OF THE NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, September 21, 1891.

SIR: In compliance with the order of the Bureau No. 3787, dated September 14, 1891, I have the honor to submit a report of the operations of the Observatory during the year ending June 30, 1891.

THE 26-INCH EQUATORIAL.

The observer on this instrument, Prof. Asaph Hall, U. S. Navy, has been engaged in completing his observations of double stars and in reducing and collecting these observations into a catalogue. This work is nearly accomplished. It is intended to make a new investigation of the periodical errors of the screw of the micrometer, and also to make some observations for the flexure and position of the instrument. This will close the work with this instrument before its removal to the new site.

For the reason stated above but few observations of satellites and other objects, except double stars, have been made. Some of these stars are close and difficult objects, which can be observed only on fine nights, and hence they have required a good deal of time.

THE TRANSIT CIRCLE.

This instrument, in charge of Prof. J. R. Eastman, U. S. Navy, was employed in observations of the sun, moon and planets, and such stars as were necessary for clock and instrument corrections. Observations of the list of stars for the Coast and Geodetic Survey were completed in 1890. Since July 1, 1890, 1,875 observations have been made with the transit circle. Of these 92 were of the sun, 53 of the moon, 48 of Mercury, 69 of Venus, 5 of Jupiter, and 5 of Saturn. The assistants on the transit circle were: Assistant Astronomers A. N. Skinner and Asaph Hall, jr.; Computers Charles S. McCoy and George A. Hill. The limited number of observers has prevented any work on the zone -14° to -18°.

The transit-circle work for 1887 is in type and that for 1888 will soon be ready for the printer. In addition to their work on astronomical reductions, the computers have reduced and prepared for publication, under Prof. Eastman's direction, the meteorological observations and results for the years 1883, 1884, 1885, 1886 and 1887. This meteorological work will form Appendix 3 to the volume for 1887. Of the reductions of the transit-circle work for 1889 more than half has been completed.

THE 9.6-INCH EQUATORIAL.

This instrument, in charge of Prof. Edgar Frisby, U. S. Navy, has been used in the observations of comets, asteroids, occultations of stars by the moon, and some miscellaneous observations of stars whose position needed identification. Observations of five different comets and of seven asteroids were made as often as possible; observations were also made of seven occultations of stars and of the transit of Mercury. The

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observations are all reduced to date and most of the results have already been communicated to astronomical journals.

Two nights in each week have been set apart for the accommodation of visitors.

THE TRANSIT OF MERCURY.

The transit of Mercury over the sun's disk, which occurred on May 9, 1891, was observed with the 9.6-inch equatorial by Prof. Frisby. The transit was only partial in the United States. On the Pacific coast the sun was two or three hours high at the time of the first and second contacts; it had set in most places on the Atlantic coast before the first contact, and in Washington it was only about ten minutes high. The afternoon of the day was quite cloudy, but just before the time of transit the clouds broke away and the first and second contacts were quite successfully observed; but, on account of the unfavorable circumstances and the sun's low altitude, the observations can not be very valuable, although the first indentation on the sun's limb was recorded on the chronograph.

In answer to a circular issued by the Observatory, requesting different astronomers throughout the country to observe the transit, responses were received from about twenty-five observers. The discussion of all these reports will doubtless increase our knowledge of the motion of this planet.

TRANSITS OF VENUS.

The reduction and discussion of the photographs of the transit of Venus, which occurred in December, 1882, is finished in the sense that results have been attained for the solar parallax and certain elements of the orbit of Venus, which are final, except in so far as they may be affected by possible small changes in the adopted longitudes of the various stations. Nevertheless some occultations of stars by the moon, telegraphic determinations of differences of longitude, tidal observations, and pendulum experiments still remain to be reduced, and as no funds are available for that purpose the work proceeds very slowly.

By the resolutions of April 10 and June 22, 1879, Congress provided for printing the observations of the transit which occurred in December, 1874, and under these resolutions Senate Ex. Doc. No. 31, Forty-sixth Congress, First session, containing 157 quarto pages, has been published, and 564 additional pages are now in type but have not yet been printed. Hitherto no provision has been made for printing the observations of the transit of December, 1882, but it is hoped that this may soon be done, because the work has now arrived at a stage where these observations should be introduced in order to show how a single result has been derived from the two transits. The meager statement of the results attained has been made in the report of the Superintendent of the Observatory for the year 1889, but until the observations are published in the detailed form adopted by other great nations the benefits accruing from the money already expended can not be fully realized.

SOLAR ECLIPSE OF 1893 APRIL 15.

On April 15, 1893, a total solar eclipse occurs under circumstances so favorable that its observation is extremely desirable. The central line of the shadow sweeps across South America, the Atlantic Ocean, and

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the northwestern part of Africa, and the duration of totality is $4^m\ 42^s$ near Ceara, Brazil, and $4^m\ 10^s$ near Bathurst, Senegambia. Many of the most important questions relating to the constitution of the sun can be studied only during total eclipses, and, as the whole time available for that purpose is only about three hours in a century, the necessity for utilizing every available eclipse is evident if we are ever to comprehend that wonderful orb upon which the very existence of the human race depends. It is hoped that means may be provided for sending at least one party to Ceara, and, if possible, another to Bathurst.

THE MERIDIAN TRANSIT INSTRUMENT.

The transit instrument has been constantly in use during the year for the daily observations to determine the errors of the standard-mean-time and other clocks for use in the transmission of standard time, and for the comparison of the chronometers. Observations have been taken with this instrument on every favorable night. The clocks continue to perform well, their rates seeming to follow the barometric movement more than any thermometric or hygrometric change.

A portable transit has been mounted and adjusted for use during the transfer and mounting of the large instrument at the new observatory.

The meridian transit instrument was in charge of Lieut. B. W. Hodges, U. S. Navy, until September 1, 1890, when he was relieved by Ensign Thomas Snowden, U. S. Navy. Ensign Hugh Rodman, U. S. Navy, assisted in the work with this instrument until relieved by Ensign H. H. Whittlesey, U. S. Navy.

CHRONOMETERS AND TIME SERVICE.

During the year 60 chronometers were issued, 37 turned in, 18 purchased, and 63 surveyed, of which 51 were sold and 12 retained for use in the Observatory.

Forty-six chronometers were repaired by the different firms and 20 are now undergoing repairs.

Of the chronometers owned by the government, 12 are in use at the Observatory, 53 are ready for issue, 17 await trial, 7 hack chronometers are ready for issue, 114 chronometers and 42 hacks are in use on naval vessels, 39 chronometers and 12 hacks are at the Mare Island observatory for issue to vessels, 17 chronometers and 20 hacks are in use on receiving ships, at shore stations, and for scientific purposes, 10 are held for survey, 17 are held for the Observatory museum, and 25 are awaiting repairs.

Besides the above instruments, there are 5 pocket chronometers, 23 watches, and 27 thermometers for issue, 2 watches requiring repairs; 8 watches and 2 thermometers are held for survey.

The Bureau of Equipment, having notified the several chronometer makers of the intention of the government to purchase a number of chronometers for the naval service, Messrs. T. S. & J. D. Negus submitted 16, John Bliss & Co. 13, H. H. Heinrich 8, and William Bond & Son 4 chronometers for competitive trial, of which number 18 were purchased. The trial of these chronometers began January 1, 1891, and was completed June 9, 1891. The results of the trial are appended in Table A.

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Besides this trial, two trials of repaired chronometers were held during the year, lasting three months each, the results of which are appended in Tables B and C. These trials were conducted in the same manner as those of preceding years, which have been described at length.

The time service has been satisfactory, the usual signals having been sent over the connecting wires, the same number of time-balls dropped, the Government clocks corrected, and the fire-alarm-circuit signals sent out, as formerly. This division of the Observatory, comprising the chronometers and the time service, was in charge of Lieut. Hiero Taylor, U. S. Navy, until May 1, when he was relieved by Ensign Thomas Snowden, U. S. Navy. Ensign H. P. Jones, U. S. Navy, and Ensign H. H. Whittlesey, U. S. Navy, have assisted in the chronometer work.

NAUTICAL INSTRUMENTS.

The instruments used in the navigation of ships have been carefully examined by Lieutenant-Commander Walton Goodwin, U. S. Navy, before acceptance, and distributed as directed by the Chief of the Bureau of Equipment.

A number of octants have been fitted with the telescope with large object-glass, for night observations. The binocular and spy glasses received during the year are of a quality superior to those formerly issued to the naval service.

A number of old chronometers, sextants, octants, and other instruments were condemned by survey as unserviceable, obsolete, and worn out, and were sold.

Two thousand three hundred and sixty permits were issued for a view of the heavens through the telescope.

MAGNETIC INSTRUMENTS.

The magnetic observations were under the charge of Ensign J. A. Hoogewerff, U. S. Navy. Ensign W. B. Hoggatt, U. S. Navy, was assistant until January 27, and Ensign R. E. Coontz, U. S. Navy, until June 30.

The self-recording magnetographs have been in operation continuously during the year, and the traces made by them developed, measured, and recorded. Experiments to determine the scale-values in terms of the force, and the temperature-corrections of the horizontal and vertical-force instruments, have been made as frequently as necessary throughout the year.

Observations of the absolute declination (variation of the compass) have been made twice a day during the year, between 9 and 10 a. m. and noon and 3:30 p. m, and the values of the base lines of the declination traces deduced from them.

Observations of the horizontal intensity of the earth's magnetic force have been made on four days of each month.

Two observations of the magnetic inclination (dip) have been made on each of the four days of each month on which the horizontal intensity was observed.

The actual number of the absolute observations is as follows: 503 observations of declination, 21 of horizontal intensity, and 84 of inclination.

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The results of the absolute observations have been reduced and combined with the continuous photographic records, and the absolute declination, horizontal force, and vertical force of the earth's magnetism were found and tabulated for each hour of the year.

The reduced observations for 1888 and 1889 have been published, and those for 1890 are now in the hands of the printer.

Two seismoscopes and a seismograph have been kept in working order during the year.

A report by Ensign C. C. Marsh, U. S. Navy, on "Some of the Magnetic Observatories of Europe" has been prepared for publication and is now at the Printing Office.

A continuous graphic record of the variation of the compass at this observatory since March 29, 1891, has been furnished to the Hydrographic Office, and has been published by it on the Monthly Pilot Chart of the North Atlantic Ocean.

LIBRARY AND PUBLICATIONS.

The library, together with the distribution of the publications of the Observatory, has remained in charge of Assistant Astronomer H. M. Paul.

The contents of the library at the beginning and end of the fiscal year 1890–91, with the additions during the year, were as follows:

	Volumes.	Pamphlets.	Total.
Contents, 1890 June 30	12,643	2,915	15,558
Additions	559	146	705
Contents, 1891 June 30	13,202	3,061	16,263

Of the 705 additions, 391 were received in exchange and 314 by purchase.

About 350 volumes have been bound during the year, but this does not suffice for the growth of the library. The binding has fallen very far behind, on account of the frequent suspension of work upon requisitions, and it is now practically two years in arrears. Some of the books now at the bindery have been there already more than eight months. The only apparent remedy for these difficulties is in granting the Observatory its own fund for binding, and a considerable increase in the estimate for the library has been submitted for this purpose, which it is hoped may have the approval of the Bureau and the Department.

The following publications have been distributed to the regular exchange lists:

1. The annual report of the Superintendent for 1890.
2. The Washington Observations for the year 1885.
3. The Washington Observations for the year 1886.
4. 1885, Appendix 3.—The Solar Parallax and its Related Constants, by Prof. Wm. Harkness, U. S. Navy.
5. 1886, Appendix 1.—Magnetic Observations, 1888-89, by Ensign J. A. Hoogewerff, U. S. Navy.

The annual volume for 1887 will shortly be ready for distribution, and that for 1888 is nearly ready for the printer.

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NEW NAVAL OBSERVATORY.

The new Naval Observatory buildings are not yet completed, and from present indications the removal from the old to the new Observatory will not be accomplished until July, 1892.

Very respectfully,

F. V. McNAIR,
Captain U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

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TABLE A.—*Record of competitive trial*

[In temperature room January 1 to March 14; after that to May

Relative number.	Time, 1891		Jan. 2 to Jan. 9.	Jan. 10 to Jan. 17.	Jan. 18 to Jan. 25.	Jan. 25 to Feb. 2.	Feb. 3 to Feb. 10.	Feb. 11 to Feb. 18.	Feb. 19 to Feb. 26.	Feb. 27 to Mar. 6.	Mar. 7 to Mar. 14.
	Temperature, Fahrenheit		45.04	54.95	70.03	85.09	90.04	85.01	69.93	55.03	45.30
	Relative humidity, per cent		65.3	69.4	68.8	69.9	68.0	68.6	69.3	69.6	70.1
	Chronometer maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	John Bliss & Co.....*a*	2827	−1.226	−1.324	−1.086	−1.646	−1.909	−1.617	−1.150	−1.243	−1.660
2	.....do.....*a*	2860	+0.596	+0.069	−0.371	−0.289	+0.199	+0.097	−0.114	−0.029	+0.269
3	T. S. & J. D. Negus ...*b*	1774	+0.524	+0.926	+0.771	+0.854	+1.127	+0.811	+0.386	+0.329	+0.876
4	.....do.....*b*	1783	+2.060	+2.176	+2.093	+1.676	+2.199	+1.704	+2.207	+2.150	+1.840
5	John Bliss & Co.....*a*	2843	+0.346	+0.319	+0.521	+0.569	+0.806	+0.633	+0.636	+0.757	+0.769
6	.....do.....*a*	2858	+1.381	+0.104	−0.228	+0.569	+1.056	+0.490	−0.150	+0.007	+0.840
7	Wm. Bond & Son .....*c*	425	−0.762	−0.360	+0.164	+0.319	+0.341	+0.490	+0.207	−0.457	−0.231
8	T. S. & J. D. Negus ...*d*	1764	+2.810	+1.961	+1.707	+2.497	+3.091	+2.490	+2.029	+2.400	+3.340
9	John Bliss & Co.....*a*	2829	+1.846	+1.069	+0.736	+0.211	+0.556	+0.633	+0.564	+1.114	+1.019
10	.....do.....*a*	2851	+1.810	+1.640	+0.807	+0.354	+0.663	+0.490	+0.707	+1.114	+1.519
11	.....do.....*a*	2837	−0.619	−2.253	−3.228	−2.967	−2.480	−3.010	−3.114	−2.207	−0.910
12	H. H. Heinrich.....*e*	1007	+1.953	+0.461	−0.050	+0.926	+1.199	+0.704	+0.064	+0.471	+1.519
13	Wm. Bond & Son .....*c*	504	+0.310	+1.997	+2.593	+3.033	+3.127	+3.026	+2.957	+1.864	+1.126
14	T. S. & J. D. Negus ...*b*	1776	+2.846	+2.283	+2.307	+1.854	+2.591	+2.633	+2.243	+2.436	+2.983
15	John Bliss & Co.....*a*	2792	−0.833	−0.681	+0.057	+0.140	+0.020	−0.046	+0.171	−0.529	−1.410
16	T. S. & J. D. Negus....*b*	1777	−0.404	−0.824	−0.550	−0.181	−0.087	−0.260	−0.150	−0.743	−0.410
17	.....do.....*d*	1801	+2.096	+1.533	+1.414	+2.319	+3.163	+2.597	+1.814	+2.007	+2.697
18	.....do.....*b*	1787	−0.476	+0.069	+0.093	+0.211	+0.413	−0.010	−0.721	−0.529	−0.410
19	.....do.....*b*	1780	−0.654	−1.574	−1.336	−1.146	−0.801	−1.010	−1.471	−1.636	−1.267
20	H. H. Heinrich.....*f*	1001	+0.131	−0.467	+0.271	+1.104	+1.270	+1.383	+0.421	+0.186	+0.307
21	T. S. & J. D. Negus ...*d*	1802	+1.453	+0.140	−0.764	−0.467	−0.051	−0.689	−1.079	−0.171	+1.161
22	.....do.....*d*	1765	+2.024	+0.604	−0.229	+0.783	+1.306	+0.954	+0.029	+0.686	+2.019
23	John Bliss & Co.....*a*	2850	+1.203	+0.069	−0.621	−0.967	−0.587	−1.189	−0.364	+0.614	+1.054
24	T. S. & J. D. Negus ...*b*	1782	+3.417	+2.604	+2.093	+1.997	+1.949	+2.847	+2.386	+2.686	+3.411
25	.....do.....*b*	1784	+1.596	+2.176	+2.807	+2.854	+3.484	+3.347	+3.457	+2.721	+2.697
26	.....do.....*d*	1718	+1.667	+0.247	−0.336	+0.997	+1.663	+1.204	+0.171	+0.686	+2.126
27	John Bliss & Co.....*a*	2855	+2.167	+0.890	−0.121	+1.069	+1.984	+1.633	+0.921	+0.900	+2.054
28	Wm. Bond & Son .....*d*	480	+0.453	−0.503	+0.307	+1.997	+2.627	+2.061	+0.529	+0.150	+0.876
29	H. H. Heinrich .....*g*	712	+0.560	+0.747	+1.236	+1.319	+2.020	+1.811	+2.171	+2.114	+1.697
30	John Bliss & Co.....*a*	2810	+2.417	+0.461	+0.414	+0.140	+0.127	−0.046	+0.564	+1.114	+1.554
31	H. H. Heinrich .....*h*	1005	+0.810	+0.461	+0.664	+0.568	+0.163	−0.260	+0.600	+0.686	+1.197
32	Wm. Bond & Son .....*i*	1009	+1.524	+1.461	+2.664	+2.854	+2.377	+2.454	+2.886	+2.257	+2.019
33	John Bliss & Co.....*a*	2852	+2.453	+1.926	+0.771	+1.176	+1.984	+1.454	+1.100	+2.400	+3.269
34	T. S. & J. D. Negus ...*b*	1772	+0.810	+0.319	+0.236	+0.854	+1.306	+1.490	+1.636	+1.650	+2.126
35	H. H. Heinrich.....*e*	1002	+1.917	+1.033	−0.407	−1.217	−0.623	−1.153	−1.436	−0.207	+1.161
36	T. S. & J. D. Negus ...*d*	1737	+2.560	+1.461	+1.093	+1.783	+2.413	+2.097	+2.457	+3.114	+3.626
37	H. H. Heinrich.....*j*	1003	+1.667	+1.890	+1.271	+1.604	+1.913	+1.169	+0.386	+0.436	+3.019
38	John Bliss & Co.....*a*	2828	+0.953	+1.033	+0.879	+0.211	+0.949	+1.097	+2.136	+2.114	+1.447
39	H. H. Heinrich.....*k*	1008	−1.154	−0.360	−0.121	+0.176	+0.341	+0.311	+1.993	−0.171	−0.267
40	T. S. & J. D. Negus ...*b*	1786	+0.310	+0.533	+0.736	+0.890	+0.984	+0.954	+0.529	+0.150	−0.089
41	H. H. Heinrich.....*l*	1004	−1.047	+0.783	−0.050	−1.360	−2.873	−3.153	−1.614	−0.850	−0.660

NOTE.—The sign + signifies losig; − signifies gaining.
a Ordinary balance with Bliss corrector.
b Ordinary balance with Negus correction.
c Hartnup balance.
d Ordinary balance.
e Heinrich regulator, white steel spring.
f Heinrich compensating weights, white steel spring.

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of chronometers, January to June, 1891.

28, in chronometer room; then in temperature room to June 9.]

Mar. 14 to Mar. 21.	Mar. 21 to Mar. 28.	Mar. 28 to Apr. 4.	Apr. 4 to Apr. 11.	Apr. 11 to Apr. 18.	Apr. 18 to Apr. 25.	Apr. 25 to May 2.	May 2 to May 9.	May 9 to May 16.	May 16 to May 23.	Temperature of compensation.	Temperature-constant.	First trial number.	Final trial number.	Relative number.
56.17	60.35	57.66	57.05	66.99	74.12	70.29	68.50	72.47	71.28					
63.0	66.1	65.7	64.1	72.4	63.4	57.6	59.1	65.0	68.9					
s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	°	*s.*			
−1.369	−1.369	−1.324	−1.150	−1.157	−1.266	−1.297	−1.467	−1.496	−1.620	66.17	−.00150	5.185	6.088	1
−0.083	−0.476	−0.431	−0.364	−0.943	−1.087	−1.011	−0.967	−1.139	−1.227	72.14	+.00091	3.574	6.363	2
+0.524	+0.560	+0.569	+0.279	+0.343	+0.091	+0.203	+0.319	+0.183	+0.094	64.93	+.00067	5.633	6.914	3
+2.096	+1.917	+2.104	+1.814	+1.521	+1.270	+1.631	+1.747	+1.754	+1.916	62.05	−.00099	5.705	7.385	4
+0.774	+0.846	+1.104	+0.850	+0.414	+0.234	+0.274	+0.211	+0.183	+0.059	94.72	−.00004	3.747	7.624	5
−0.119	−0.369	−0.324	−0.293	−0.621	−0.623	−0.583	−0.681	−0.531	−0.549	66.32	+.00213	8.350	8.870	6
−0.690	−0.511	−0.431	−0.436	+0.057	+0.270	+0.274	−0.039	+0.254	+0.273	86.20	−.00084	8.539	9.531	7
+2.274	+2.024	+2.140	+1.993	+1.807	+1.484	+1.560	+1.604	+1.611	+1.559	67.51	+.00208	8.483	10.609	8
+1.060	+1.060	+0.926	+0.743	+0.771	+0.413	+0.310	+0.176	+0.040	−0.477	93.35	+.00048	6.581	11.470	9
+0.917	+0.917	+0.997	+0.886	+0.664	+0.234	+0.667	+0.569	+0.326	+0.237	94.98	+.00064	10.399	11.481	10
−2.583	−2.797	−2.467	−2.436	−3.129	−3.223	−3.261	−3.146	−3.460	−3.549	75.09	+.00250	10.978	11.569	11
+0.560	+0.381	+0.176	+0.421	−0.157	−0.409	−0.369	−0.324	−0.389	−0.334	67.95	+.00280	10.321	12.346	12
+2.203	+2.489	+2.283	+2.136	+2.593	+2.806	+2.596	+2.426	+2.861	+2.630	83.97	−.00131	11.123	12.355	13
+2.453	+2.239	+1.961	+1.993	+1.700	+1.377	+1.381	+1.247	+1.040	+0.844	86.18	+.00012	8.231	12.755	14
−0.976	−0.690	−0.681	−0.650	−0.729	−0.551	−0.571	−0.610	−0.689	−0.763	76.24	−.00174	9.562	12.933	15
−0.940	−1.011	−1.039	−1.007	−0.943	−0.944	−1.011	−1.074	−0.853	−0.799	83.82	−.00068	12.090	13.035	16
+1.703	+1.631	+1.747	+1.707	+1.271	+1.449	+1.489	+1.426	+1.290	+1.166	64.84	+.00221	11.947	13.411	17
−0.440	−0.690	−0.646	−0.757	−0.693	−0.730	−0.833	−1.039	−0.853	−1.013	65.11	+.00111	12.886	13.711	18
−1.690	−2.190	−1.967	−2.043	−2.550	−2.194	−1.904	−1.717	−1.889	−1.977	37.98	+.00027	10.039	15.371	19
−0.047	−0.190	−0.289	−0.329	−0.264	−0.016	−0.333	−0.217	−0.210	−0.441	44.47	−.00090	13.435	15.412	20
+0.096	−0.404	−0.503	−0.471	−1.157	−1.694	−1.690	−1.646	−1.746	−1.727	73.39	+.00277	12.946	16.310	21
+0.667	+0.167	+0.390	+0.421	−0.336	−0.516	−0.333	−0.289	−0.389	−0.477	69.05	+.00379	15.465	16.910	22
+0.524	−0.047	+0.211	−0.007	−1.086	−1.516	−1.083	−1.039	−1.139	−1.191	112.07	+.00057	16.031	20.521	23
+2.881	+1.987	+2.640	+3.100	+2.664	+2.806	+2.917	+1.926	+2.147	+2.809	72.87	−.00130	11.419	21.191	24
+2.739	+2.703	+2.283	+2.207	+2.557	+2.877	+2.631	+2.461	+2.647	+2.487	76.86	−.00158	20.123	22.226	25
+0.810	+0.917	+1.247	+1.350	+0.843	+0.841	+0.881	+0.890	+0.861	+0.809	67.27	+.00383	20.803	22.817	26
+0.667	+0.631	+0.890	+0.957	+0.629	+0.913	+1.024	+1.247	+1.111	+0.987	67.65	+.00320	21.626	23.755	27
−0.047	−0.190	−0.217	−0.257	−0.229	+0.020	−0.369	−0.467	−0.317	−0.477	53.61	+.00224	23.165	26.532	28
+1.739	+1.739	+1.604	+1.493	+1.307	+1.127	+1.167	+1.211	+1.147	+1.201	72.46	−.00091	27.849	30.013	29
+0.846	+0.881	+1.104	+1.529	+0.700	+0.056	+0.239	+0.247	−0.317	−0.477	30.53	−.00031	21.483	30.537	30
+0.739	+0.096	−0.181	−0.400	−0.764	−1.373	−1.583	−1.824	−1.996	−1.977	64.12	−.00118	14.886	31.943	31
+1.917	+2.167	+2.319	+2.243	+2.771	+3.484	+3.703	+3.854	+4.040	+4.201	75.77	−.00230	25.572	32.573	32
+0.953	+0.739	+1.176	+1.350	+0.129	−0.266	+0.024	+0.069	−0.031	+0.094	73.98	+.00356	31.668	33.448	33
+1.596	+1.703	+1.676	+1.636	+1.593	+1.449	+1.596	+1.604	+1.504	+1.487	65.06	−.00064	35.867	36.305	34
−0.654	−1.119	−1.289	−0.864	−1.050	−1.194	−1.297	−1.289	−1.281	−1.299	81.18	+.00238	35.207	42.698	35
+2.417	+2.060	+2.283	+2.279	+1.414	+1.306	+1.274	+1.319	+1.183	+1.139	73.87	+.00150	40.757	44.258	36
+2.060	+1.810	+1.283	+1.279	+1.236	+0.591	+0.310	−0.181	+0.076	+0.309	68.13	+.00197	32.817	44.262	37
+1.631	+1.024	+0.711	+0.493	+0.486	+1.341	+1.631	+1.354	+1.397	+1.523	61.22	−.00174	35.369	46.861	38
−0.690	−0.547	−0.539	−0.936	−0.229	+0.091	−0.047	−0.396	−0.710	−0.334	72.04	−.00420	75.646	79.132	39
−0.119	−0.154	−0.146	−0.221	−0.371	−0.480	−0.476	−0.574	−0.674	−0.763	1300.04	−.000008	78.687	81.334	40
−1.226	−1.511	−2.074	−3.543	−1.586	−2.801	−3.511	−3.289	−3.210	−3.441	43.12	−.00137	81.167	136.075	41

g Heinrich auxiliary self-adjusting balance; Giles non-magnetic shield.
h Ordinary balance, palladium spring.
i Paillard's non-magnetic balance, palladium spring.
j Ordinary balance, white steel spring.
k Plain compensation balance, palladium spring.
l Heinrich regulator, palladium spring.

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TABLE B.—*Record of trial of repaired chro*

[In temperature room from November 1 to De

Relative number.	Repaired by.	Time, 1890–91		Nov. 5 to Nov. 10.	Nov. 11 to Nov. 16.	Nov. 17 to Nov. 22.	Nov. 23 to Nov. 28.	Nov. 29 to Dec. 4.	Dec. 6 to Dec. 11.	Dec. 13 to Dec. 18.	Dec. 19 to Dec. 24.	Dec. 25 to Dec. 30.	Jan. 3 to Jan. 8.	Jan. 8 to Jan. 13.
		Temperature, Fahrenheit.		90°.0	84°.9	69°.8	55°.1	45°.5	54°.6	70°.2	84°.8	89.°00	54°.5	56°.5
		Relative humidity, per cent.....		70.0	67.9	63.3	70.1	69.0	71.2	67.8	67.2	57.5	.....	.....
		Chronometer-maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	Bd	Wm. Bond & Son.	218	+1.356	+0.908	+0.300	+0.568	+1.552	+0.982	+0.204	+0.706	+1.152	+0.974	+0.542
2	Bd	....do	287	+1.806	+1.608	+1.950	+1.768	+2.102	+1.982	+2.104	+1.806	+2.152	+1.824	+1.442
3	Bl.	John Bliss & Co.	2817	+1.106	+0.858	+1.100	+0.518	+0.952	+0.632	+0.704	+0.506	+1.252	+1.374	+1.392
4	Bd	Wm. Bond & Son.	290	+1.156	+1.308	+0.500	+0.468	+1.202	+0.882	+0.204	+0.506	+0.852	+0.824	+0.642
5	Bd	....do	221	+1.356	+1.058	+0.250	−0.132	+0.102	+0.182	+0.654	+0.606	+0.552	−0.176	−0.108
6	Bl.	Barraud ..	2609	+0.806	+0.558	+0.400	+1.468	+3.202	+1.682	+0.454	+0.706	+0.902	+2.024	+1.442
7	Bl.	Dent.....	2394	+0.006	+0.558	+0.150	−0.432	−1.298	−0.468	+0.654	+1.006	+1.302	+0.174	+0.692
8	Bd	Wm. Bond & Son.	292	+1.756	+1.458	+0.700	+0.618	+1.502	+0.832	+1.154	+1.406	+1.902	+1.624	+1.442
9	Bd	Hutton ...	349	−0.044	−0.392	−0.500	+0.518	+1.502	+0.382	−0.946	−0.944	−0.298	+0.924	+0.442
10	Bl.	Dent.....	29480	−2.094	−1.842	−1.350	−0.582	+0.252	−0.018	−0.496	−1.744	−2.098	−0.776	−0.758
11	Bl.	Poole	2381	−1.194	−1.342	−1.100	+0.018	+1.602	+0.232	−0.746	−1.244	−0.598	+1.124	+0.342
12	Bl.	Dent.....	25568	−0.194	+0.558	+0.600	+1.018	+2.852	+0.682	+0.104	+0.306	−0.152	+0.624	+0.342
13	Bl.	Poole	1940	+0.556	+0.408	−0.550	−0.382	+0.302	−0.468	−1.296	−0.594	+0.202	−0.826	−0.608
14	Bl.	Usher & Cole.	464	+1.406	+1.308	+1.900	+3.218	+4.802	+2.882	+1.004	+0.756	+1.502	+3.024	+2.742
15	Bd	Frodsham.	3276	+0.506	−0.392	−2.150	−1.532	−0.898	−1.368	−1.646	−0.694	−0.948	−2.526	−2.758
16	Bd	Wm. Bond & Son.	339	+2.356	+1.108	−0.550	−0.032	+1.452	+0.632	+0.654	+1.756	+2.302	+0.824	+0.442
17	Bd	....do	493	+3.806	+3.308	+1.250	+0.968	+0.602	+0.932	+1.654	+2.956	+4.102	+1.724	+1.142
18	Bd	Frodsham.	2831	+4.256	+3.458	+2.300	+3.518	+4.302	+3.832	+3.054	+3.456	+3.102	+3.624	+2.742
19	Bd	Wm. Bond & Son.	509	+2.856	+2.408	+0.300	+0.168	+0.152	+0.382	+1.054	+2.206	+2.502	+1.274	+0.992
20	Bl.	Penlington	1742	+0.656	−0.342	−0.050	+1.218	+2.752	+1.482	+0.054	−0.344	+0.702	+3.274	+1.042
21	Bl.	Crisp	2101	+2.856	+2.608	+3.400	−0.282	+0.152	−1.368	+0.654	+1.906	+2.902	+1.924	+1.142

TABLE C.—*Record of trial of repaired*

[In temperature room from January 1 to

Relative number.	Repaired by.	Time, 1891.....		Jan. 2 to Jan. 9.	Jan. 10 to Jan. 17.	Jan. 18 to Jan. 25.	Jan. 25 to Feb. 2.	Feb. 3 to Feb. 10.	Feb. 11 to Feb. 18.	Feb. 19 to Feb. 26.	Feb. 27 to Mar. 6.	Mar. 7 to Mar. 14.	Mar. 14 to Mar. 21.
		Temperature, Fahrenheit..		45°. 04	54°. 95	70°. 03	85°. 09	90°. 04	85°. 01	69°. 93	55°. 03	45°. 30	56°. 17
		Relative humidity, per cent.....		65. 3	69. 4	68. 8	69. 9	68. 0	68. 6	68. 3	69. 6	70. 1	63. 0
		Chronometer-maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	Neg.	T. S. & J. D. Negus.	1215	+1. 453	+0. 676	+0. 664	+1. 426	+1. 627	+1. 097	−0. 636	+1. 186	+2. 054	+0. 846
2	Neg.	....do	1721	+1. 739	+0. 426	−0. 193	+0. 569	+0. 949	+0. 811	−0. 007	+0. 543	+1. 733	+0. 239
3	Neg.	....do	1762	+2. 453	+1. 426	+1. 343	+2. 426	+3. 270	+2. 669	+1. 886	+1. 864	+2. 519	+1. 024
4	Neg.	....do	1448	+0. 810	−0. 181	−0. 371	+0. 890	+1. 663	+1. 061	−0. 186	+0. 221	+0. 911	−0. 369
5	Neg.	....do	1773	+1. 953	+1. 890	+0. 950	+0. 961	+1. 127	+0. 919	+1. 279	+2. 329	+2. 804	+1. 953
6	Neg.	....do	1464	−0. 119	−1. 181	−1. 193	−0. 181	+0. 699	+0. 276	−0. 543	−0. 207	+0. 840	−0. 690
7	Neg.	....do	1739	+3. 381	+1. 211	−0. 229	+0. 497	+0. 877	+0. 454	+0. 100	+1. 293	+2. 733	+1. 131
8	Neg.	....do	1605	+0. 024	+0. 104	+0. 486	+1. 711	+2. 449	+1. 704	+1. 171	+0. 793	+1. 090	+1. 239
9	Neg.	....do	729	+1. 203	−0. 253	−0. 443	+0. 783	+1. 949	+1. 204	+1. 100	+1. 364	+1. 661	+0. 346
10	Neg.	....do	1283	−0. 333	−1. 431	−1. 693	−0. 576	−0. 016	−0. 724	−3. 043	−3. 243	−1. 839	−3. 261
11	Neg.	....do	1748	−0. 011	+0. 426	+0. 771	+0. 569	+0. 484	+0. 740	+0. 314	+0. 436	+0. 840	+1. 024

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nometers, November 1, 1890, to March 4, 1891.

cember 31; after that in chronometer room.]

Jan. 13 to Jan. 18.	Jan. 18 to Jan. 23.	Jan. 23 to Jan. 28.	Jan. 28 to Feb 2.	Feb. 2 to Feb. 7.	Feb. 7 to Feb. 12.	Feb. 12 to Feb. 17.	Feb. 17 to Feb. 22.	Feb. 22 to Feb. 27.	Feb. 27 to Mar. 4.	Temperature of compensation.	Temperature-constant.	First trial number.	Final trial number.	Relative number.
57°.7	59°.0	59°.4	61°.3	59°.6	60°.0	59°.5	64°.3	61°.9	54°.3					
s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.			
+0.338	+0.270	+0.164	+0.084	+0.154	+0.022	+0.164	−0.118	+0.004	+0.336	60.63	+.00241	7.720	9.295	1
+1.138	+1.420	+1.214	+1.384	+1.354	+1.522	+1.414	+1.282	+1.304	+1.436	67.20	−.00106	6.619	9.543	2
+1.488	+1.670	+1.714	+1.984	+1.904	+1.872	+2.014	+1.982	+1.954	+1.636	71.32	−.00122	12.556	13.258	3
+0.488	+0.470	+0.264	+0.534	+0.454	+0.422	+0.464	+0.832	+0.704	+0.486	67.88	+.00197	11.564	14.488	4
−0.162	−0.180	−0.286	−0.216	−0.146	−0.228	−0.436	−0.418	−0.446	−0.564	223.97	−.00009	15.069	15.870	5
+1.038	+1.070	+0.914	+0.884	+0.904	+0.872	+1.014	+0.632	+0.454	+1.386	75.15	+.00299	14.289	16.769	6
+0.738	+0.770	+0.864	+1.034	+0.754	+0.922	+0.914	+0.932	+0.854	+0.136	89.89	−.00103	16.216	17.632	7
+1.038	+1.070	+0.964	+0.684	+0.604	+0.372	+0.664	+0.032	+0.204	+0.986	52.78	+.00069	9.167	21.138	8
+0.088	+0.120	+0.064	+0.084	+0.454	+0.622	+0.414	+0.282	+0.354	+1.586	76.68	+.00273	17.883	21.380	9
−0.762	−0.730	−0.736	−0.566	−0.746	−0.728	−0.536	−0.668	−0.496	−0.814	27.13	−.00058	18.437	21.677	10
−0.062	+0.170	−0.236	−0.116	+0.004	−0.278	−0.136	−0.718	−0.646	+0.086	85.83	+.00148	18.213	23.997	11
+0.138	−0.030	−0.236	−0.266	−0.196	−0.378	−0.286	−0.618	−0.696	−0.064	75.30	+.00128	21.949	24.445	12
−0.462	−0.530	−0.436	−0.316	−0.446	−0.528	−0.336	−0.468	−0.396	−0.314	67.99	+.00297	22.686	25.425	13
+2.438	+2.420	+2.514	+1.984	+2.254	+2.172	+2.214	+1.582	+1.854	+2.836	83.08	+.00252	27.218	27.680	14
−3.012	−3.030	−2.936	−2.966	−3.196	−3.328	−3.336	−3.518	−3.746	−3.314	66.11	+.00404	27.423	29.983	15
+0.338	+0.420	+0.264	+0.284	+0.304	+0.222	+0.364	+0.232	+0.254	+0.336	64.69	+.00365	29.700	30.899	16
+0.688	+0.770	+0.714	+0.884	+0.654	+0.622	+0.514	+0.532	+0.404	+0.286	56.24	+.00268	21.168	32.626	17
+2.438	+2.470	+2.264	+2.384	+2.704	+2.622	+2.814	+2.332	+2.404	+3.436	70.77	+.00397	30.095	34.547	18
+0.888	+0.920	+0.764	+0.884	+0.754	+0.872	+0.814	+0.432	+0.554	+0.986	57.67	+.00297	31.105	39.114	19
+0.488	+0.070	+0.264	−0.116	−0.146	−0.228	+0.114	−0.418	−0.246	+0.436	82.61	+.00221	22.237	69.847	20
+0.438	−0.030	−0.136	−0.866	−1.096	−0.978	−1.286	−2.568	−2.096	−2.214	78.75	−.00579	107.10	323.19	21

chronometers January 1 to May 23, 1891.

March 14; after that in chronometer room.]

Mar. 21 to Mar. 28.	Mar. 28 to Apr. 4.	Apr. 4 to Apr. 11.	Apr. 11 to Apr. 18.	Apr. 18 to Apr. 25.	Apr. 25 to May 2.	May 2 to May 9.	May 9 to May 16.	May 16 to May 23.	Temperature of compensation.	Temperature-constant.	First trial number.	Final trial number.	Relative number.
60°.35	57°.66	57°.05	66°.99	74°.12	70°.29	68°.50	72°.47	71°.28					
66.1	65.6	64.1	72.4	63.4	57.6	59.1	65.0	68.9					
s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.			
+0.667	+0.961	+0.921	+0.629	+0.484	+0.239	+0.390	+0.397	+0.380	67.23	+.00197	8.553	9.578	1
−0.047	+0.069	+0.171	−0.371	−0.337	−0.440	−0.396	−0.389	−0.477	68.90	+.00304	10.740	10.976	2
+0.667	+0.676	+0.779	+0.486	+1.091	+0.881	+0.640	+0.826	+0.666	62.96	+.00213	13.367	14.599	3
−0.511	−0.253	−0.150	−0.336	−0.230	−0.404	−0.396	−0.103	−0.191	65.39	+.00343	16.941	17.929	4
+1.703	+1.819	+1.743	+1.379	+0.877	+1.131	+1.069	+0.861	+0.916	80.70	+.00182	19.248	20.136	5
−0.619	−0.610	−0.721	−1.264	+0.873	−0.976	−1.039	−0.996	−0.977	64.87	+.00240	22.930	25.050	6
+0.667	+0.854	+1.064	−0.086	−0.587	−0.226	−0.074	−0.174	−0.191	73.16	+.00411	23.336	25.108	7
+0.953	+0.854	+0.886	+0.986	+1.020	+0.917	+1.247	+0.611	−0.013	51.06	+.00111	19.237	30.154	8
−0.047	−0.324	−0.364	−0.479	+0.056	−0.511	−0.324	−0.067	−0.013	66.33	+.00197	44.609	48.404	9
−3.690	−3.681	−3.614	−3.800	−3.837	−4.511	−4.396	−4.281	−4.299	62.75	+.00386	64.127	68.437	10
+0.953	+0.819	+0.921	+0.986	+0.841	+0.846	+0.711	+0.719	+0.701		Indeterminate.			11

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[REPORT OF THE SECRETARY OF THE NAVY, 1892. pp. 133–140.]

REPORT

OF

THE SUPERINTENDENT

OF THE

U. S. NAVAL OBSERVATORY

FOR THE

YEAR ENDING 1892 JUNE 30

WASHINGTON
GOVERNMENT PRINTING OFFICE
1892

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REPORT OF THE SUPERINTENDENT OF THE U. S. NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
Washington, September 29, 1892.

SIR: I have the honor to present the subjoined report, called for by the Bureau's order dated August 2, 1892 (No. 3243), of the operations of the Naval Observatory during the year ending June 30, 1892.

The personnel of the establishment on July 1, 1891, consisted of the following officers:

Capt. F. V. McNair, superintendent; Lieut. Commander Walton Goodwin; Ensigns Thomas Snowden, J. A. Hoogewerff, H. H. Whittlesey; Profs. Asaph Hall, Wm. Harkness, J. R. Eastman, Edgar Frisby, and S. J. Brown. Changes have occurred as follows—reported for duty: Passed Assistant Engineer A. V. Zane, on July 17, 1891; Commander Joshua Bishop, August 5, 1891; Ensign W. W. Gilmer, August 8, 1891. Detachments: Ensign H. H. Whittlesey, on August 12, 1891; Ensign W. W. Gilmer, August 19, 1891; Ensign Thomas Snowden, April 16, 1892; Ensign J. A. Hoogewerff, June 25, 1892.

THE 26-INCH EQUATORIAL.

On October 15, 1891, Prof. Asaph Hall was retired for age, and the Observatory lost the services of one of the most illustrious astronomers of the present century. His discovery of the satellites of Mars brought renown not only to himself, but also to the naval service and to the country, and his magnificent series of measurements of double stars is comparable both in extent and accuracy with the best existing observations of the same character. Since October 15, 1891, the observer was Assistant Astronomer Asaph Hall, jr. Prof. Hall was engaged in completing his observations of double stars and in reducing and collecting them into a catalogue, which has been published by the Observatory as Appendix I to the volume for 1888. He also made observations for the flexure and position of the telescope and investigated anew the periodic errors of its micrometer screw.

Assistant Astronomer Hall was engaged in observing the satellite of Neptune, the satellites of Saturn, and the two outer satellites of Uranus. The reduction of all these observations is well advanced, and those of Neptune's satellite have been published in Gould's Astronomical Journal. They confirm the motion of the orbit plane of the satellite with respect to the orbit of Neptune which was suspected by Marth in 1886.

As Mars will be nearer the Earth during its opposition in August, 1892, than at any other time since the discovery of its satellites in 1877, it seemed fitting that Prof. Hall, the discoverer of these satellites, should have the privilege of observing them once more under such exceptionally favorable circumstances. Accordingly, the Superintendent has tendered him the use of the 26-inch telescope for that purpose, and it is expected that an excellent series of measures will be secured. This telescope will be dismounted immediately after the completion of the observations of the Mars satellites in September, and meanwhile a new and more modern mounting is being constructed for it by Messrs. Warner & Swasey, of Cleveland, Ohio. The micrometer and circles are to be illuminated by incandescent lights; a larger position circle is to be provided, and a more powerful driving clock is to take the place

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of the present one. Furthermore, the large dome at the new site is to have an elevating floor to facilitate the use of spectroscopes and other heavy apparatus. By means of these additions and improvements, there will be a gain in convenience of observation and in the amount of work accomplished.

THE TRANSIT CIRCLE.

(Prof. J. R. Eastman in charge.)

Since the annual report for 1891 the transit circle has been altered and repaired, and installed in the new observing house, which unfortunately was not finished in time to make the proposed observations of Mars. The instrument will probably be ready for use in October, 1892. The present force for transit circle work consists only of the officer in charge and two computers. The reduction of the work for 1889 is ready for the printer, and the reductions for 1890 and 1891 are nearly completed. At present, a part of the force is engaged in making a card catalogue of the stars contained in the Washington zones.

THE 9.6-INCH EQUATORIAL.

(Professor Edgar Frisby in charge.)

This instrument has been used in observing asteroids, occultations of stars by the moon, and comets, at every favorable opportunity. The observations have all been reduced, and most of the results have been published in the astronomical journals. Two nights in each week have been set apart for the accommodation of visitors.

CHRONOMETERS.

(Assistant Astronomer A. N. Skinner in charge.)

Mr. Skinner assumed charge April 26, 1892. He was assisted by Computer F. E. Dennett.

During the year 44 chronometers have been issued and 40 turned in. Forty-two standard and 13 hack chronometers are ready for issue; 5 await trial. There are in use on naval vessels 119 standard and 36 hack chronometers; at Mare Island Navy-yard, 29 standard and 14 hack chronometers; at other shore stations, 13 standard and 19 hack chronometers; surveyed and condemned 14, in museum 17, and at the makers for repairs, 44 chronometers. Pocket chronometers ready for issue, 5; in use at shore stations, 1; comparing watches ready for issue, 17.

Twenty-nine chronometers received from makers, cleaned and repaired, were on trial from January 9 to July 11, 1892. The records of this trial are given in Appendix A.

TIME SERVICE.

Owing to the detachment from duty at the Observatory of the officers connected with the time service, it was, on August 1, placed in charge of Prof. S. J. Brown, and on September 1 Computer George A. Hill was detailed as his assistant. No other changes have been made in this service.

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MERIDIAN TRANSIT INSTRUMENT.

The transit instrument has been constantly in use for determination of clock corrections in connection with the time service. Ensign Thomas Snowden was in charge until August 1, 1891, when it was necessary to place this instrument and the time service in charge of Prof. S. J. Brown, owing to the detachment of the officers engaged in this and the chronometer work. Computer Hill was his assistant.

MAGNETIC INSTRUMENTS.

The usual routine observations and reductions have been kept up during the year. The observations and reductions for 1891 were published as an appendix to the Washington Observations for 1888.

Ensign J. A. Hoogewerff was in charge until November 1, 1891, when, owing to notification by the Department that his services would be required elsewhere, he was relieved by Prof. S. J. Brown. The work was carried on conjointly by them until June 25, when Ensign Hoogewerff was detached.

LIBRARY AND PUBLICATIONS.

The library, printing, and distribution of the Observatory publications have been under the general supervision of Assistant Astronomer H. M. Paul, with William D. Horigan assistant librarian.

During the fiscal year 1891–'92 bound volumes only have been entered in the accession book. These number 299 (125 by exchange and 174 by purchase), making the total number of bound volumes in the library about 13,500. The annual accessions of unbound books, periodicals, and pamphlets amount to about 400 volumes. One hundred and sixty volumes have been bound during the year, leaving upwards of 1,000 volumes still unbound owing to want of funds.

The following publications have been distributed to the regular exchange lists:

1. The Annual Report of the Superintendent for 1891.
2. The Washington Observations for the year 1887.
3. The Washington Observations for the year 1888.
4. 1887: Appendix 1—Marsh, C. C. Magnetic Observatories of Europe.
5. 1887: Appendix 2—Hoogewerff, J. A. Magnetic Observations, 1890.
6. 1887: Appendix 3—Eastman, J. R. Meteorological Observations, 1883–'87.
7. 1888: Appendix 1—Hall, Asaph. Double-star Observations. Part 2, 1880–'91.
8. 1888: Appendix 2—Hoogewerff, J. A. Magnetic Observations, 1891.
9. 1888: pp. D. 1–60—Meteorological Observations, 1888.

TOTAL SOLAR ECLIPSE OF APRIL 15, 1893.

A total solar eclipse will occur on April 15, 1893, under circumstances so favorable that its observation is very desirable. The central line of the shadow sweeps across South America, the Atlantic Ocean, and the northwestern part of Africa. The duration of totality is 4 minutes and 42 seconds near Ceara, on the northern coast of Brazil, and 4 minutes and 10 seconds near Bathurst, Senegambia, in West Africa. It is important that this opportunity for studying the constitution of the sun should be utilized by sending two observing parties, one to Ceara, Brazil, and the other to Bathurst, West Africa.

It is recommended that expeditions be sent to those places composed entirely of officers and others under the control of the Navy Department. Independent of travel and transportation, the sum of $5,000 will

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be necessary for the purchase of instruments, outfit and contingent expenses. Such appropriation must be made available prior to January 15, 1893, to accomplish the desired observations.

NEW NAVAL OBSERVATORY.

On September 8, 1891, the contract for the construction of the new Naval Observatory was declared forfeited. On February 16, 1892, a contract was awarded for the completion of the new Naval Observatory; which contract has not been fulfilled.

The installation of boilers, engines, electric plant, stand-pipe and water-supply system will shortly be completed.

The grounds have been graded and roads constructed to the extent that the appropriation for that purpose admitted.

The Superintendent's residence is still in the hands of the contractor.

Very respectfully,

F. V. McNAIR,
Captain, U. S. Navy, Superintendent.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

Estimates of appropriations required for the service of the fiscal year ending June 30, 1894, by the United States Naval Observatory.

Detailed objects of expenditure and explanations.	Estimated amount which will be required for each detailed object of expenditure.	Total amount to be appropriated under each head of appropriation.	Amount appropriated for the current fiscal year ending June 30, 1893.
SALARIES, NAVAL OBSERVATORY			
One assistant astronomer (R. S., p. 27, sec. 167; Aug, 5, 1882, vol. 22, p. 245, sec. 1, July 16, 1892).	$2,000.00		
Two assistant astronomers, at $1,800 each (same acts)	3,600.00		
One clerk of class four (same acts)	1,800.00		
One instrument-maker (same acts)	1,500.00		
One electrician (same acts)	1,500.00		
One photographer (same acts)	1,200.00		
Five computers, at $1,200 each (same acts)	6,000.00		
One assistant librarian (same acts)	1,200.00		
One copyist (same acts)	900.00		
One carpenter (same acts)	1,000.00		
One engineer (same acts)	1,000.00		
Two assistant engineers, at $900 each (submitted)	1,800.00		
Two skilled laborers, one at $1,000 and one at $720 (same acts).	1,720.00		
Three firemen, at $720 each (same acts; increase of one submitted)	2,160.00		
Six watchmen, at $720 each (same acts)	4,320.00		
Two assistant messengers, at $720 each (submitted)	1,440.00		
One elevator conductor (submitted)	720.00		
Eleven laborers, at $660 each (same acts)	7,260.00		
Two charwomen, at $240 each (submitted)	480.00		
		41,600.00	36,440.00

NOTE.—*Assistant engineers and firemen.*—Work at the Naval Observatory is carried on at night in addition to the regular office hours. There are two boilers for heating purposes, and one boiler, two engines, and two dynamos, which, together with the extensive system of lighting, heating, and water works, require three engineers and three firemen for the 24 hours, each engineer and fireman being on duty eight hours.

Assistant messengers.—One assistant messenger to Superintendent and one for mail carrier. All mail for the Observatory is delivered at the Navy Department, which is distant from the Observatory about 2½ miles via Tennallytown road.

Elevator conductor.—The number of visitors to the Naval Observatory at night is about 2,500 per annum, the majority of whom are women, and an expert elevator conductor is essential to prevent accident.

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Estimates of appropriations required for the service of the fiscal year ending June 30, 1894, by the United States Naval Observatory—Continued.

Detailed object of expenditure, and explanations.	Estimated amount which will be required for each detailed object of expenditure.	Total amount to be appropriated under each head of appropriation.	Amount appropriated for the current fiscal year ending June 30, 1893.
CONTINGENT AND MISCELLANEOUS EXPENSES.			
Miscellaneous computations. (August 5, 1882; July 16, 1892, 22 Stat. L,, p. 245, sec. 1.)	$1,200.00		
Professional and scientific books, periodicals, engravings, photographs, fixtures, and supplies for the library, (Same acts.)	1,000.00		
Apparatus and instruments, and repairs of the same. (Same acts.)	2,500.00		
Repairs to buildings, fixtures, and fences; furniture, gas, chemicals, and stationery; freight (including transmission of public documents through the Smithsonian exchange), foreign postage and expressage; plants, fertilizers, and all contingent expenses (increase of $2,050 submitted to equal the amount approved March 3, 1891, for 1891-'92). (Same acts.)	4,550.00		
Fuel, oil, grease, tools, pipe, wire, and other materials needed for the maintenance and repairs of boilers, engines, heating apparatus, electric lighting and power plant, and water-supply system; purchase and maintenance of teams; material for boxing nautical instruments for transportation; paints, telegraph and telephone service, and incidental labor. (Same acts.)	7,500.00		
		$16,750.00	$14,700 00
NOTE.—*Repairs and all contingent expenses.*—The amount asked for ($4,550) is the same appropriated for the year 1892. The amount granted for 1893 is inadequate to meet all the unforeseen contingencies occurring in connection with the occupation of a new establishment incomplete in minor details.			
Public works under Navy Department.			
GROUNDS AND ROADS—NEW NAVAL OBSERVATORY.			
For continuing grading, extending roads and paths, clearing grounds of new Naval Observatory, and filling ravine contiguous to boiler house. (Submitted.)	12,000.00		
		12,000.00	
NOTE.—The new Observatory grounds contain 70 acres of land, much of which is rough, wooded with wild undergrowth and intersected by ravines. The heavy grading, filling, curbing, and roads have been completed in the immediate vicinity of the main building. The ravine behind the boiler house requires immediate filling to prevent the foundations of the building being undermined and washed out in heavy rains. The system of roadways and paths to connect the various buildings has been commenced.			
NEW BUILDINGS.			
For three dwellings for observers, at $10,000 each. (Submitted.)	30,000.00		
		30,000.00	
NOTE.—In order that the work of a large observatory may be properly and economically done, it is absolutely necessary that the observers be within prompt call to their instruments throughout day and night. Very important observations can often be secured from the clearing of the sky for a few hours, or even in some cases for a few minutes, if the observer be within easy call by the watchman. This can only be accomplished, in the isolated situation of the new Observatory, by having dwellings upon the grounds for the observers. The Government erects dwellings at all its navy-yards, arsenals, forts, and schools for the officers on duty there. But no service requires such unremitting attention and constant presence at all hours as that of the astronomer, and no observatory can be regarded as economically managed which does not furnish dwellings for all its observers close by their instruments. It is estimated that with the observers living on the grounds of the new Observatory, not only will two or three times as much work be done as it will be possible to do otherwise, but the quality of this delicate work will be materially improved on account of the observers being in a proper physical condition to begin their labors, instead of with nerves unstrung from hurrying some miles from their homes immediately after meals, or at unreasonable hours of the night.			

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Estimates of appropriations required for the service of the fiscal year ending June 30, 1894, by the United States Naval Observatory—Continued.

Detailed object of expenditure, and explanations.	Estimated amount which will be required for each detailed object of expenditure.	Total amount to be appropriated under each head of appropriation.	Amount appropriated for the current fiscal year ending June 30, 1893.
STATIONARY FIRE ENGINE.			
For 1 stationary fire engine, with pipes, connections and frame shelter. (Submitted.)	$4,500.00	$4,500.00	
NOTE.—The capacity of the present pumping-engines and stand pipe is not adequate for the extinction of any extensive fire. It is proposed, therefore, to utilize the pond in the Industrial Home grounds, adjoining the Observatory grounds, as a reserve.			

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Record of trial of repaired chronometers, January 9 to July 11, 1892.

[In temperature room from January 9 to March 12; after that in chronometer room.]

Relative number.	Repaired by—	Time, 1892		Jan. 9 to Jan. 14.	Jan. 15 to Jan. 20.	Jan. 21 to Jan. 26	Feb. 5 to Feb. 10	Feb. 11 to Feb. 16.	Feb. 17 to Feb. 22.	Feb. 23 to Feb. 28.	Mar. 1 to Mar. 6.	Mar. 7 to Mar. 12.	Mar. 13 to Mar. 23.	Mar. 23 to Apr. 2.	Apr. 2 to Apr. 12.	Apr. 12 to Apr. 22.
		Temperature		44°.67	55°.12	70°.13	84°.80	90°.10	85.°23	69°.80	54°.74	45°.35	56°.81	62°.52	69°.51	63°.25
		Relative humidity, per cent.		69.97	67.76	70.60	66.89	68.12	70.81	70.76	67.88	73.44	.....	.....	.....	.....
		Chronometer-maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
1	Neg...	John Hutton	372	+1.508	+0.446	—0.036	+0.740	+1.478	+1.058	+0.404	+0.686	+1.872	+0.572	+0.093	—0.218	—0.168
2	Neg...	T. S. & J. D. Negus	1596	+1.428	+0.496	+0.214	+1.040	+1.378	+1.058	+0.104	+0.586	+1.772	+0.897	+0.668	+0.556	+0.482
3	Neg...	do	1036	+1.308	+0.196	—0.786	—0.110	+0.178	—0.192	—0.346	+0.386	+1.572	—0.078	—0.757	—1.019	—0.868
4	Bl	John Bliss & Co	2827	+0.558	+1.196	+1.764	+1.290	+1.278	+1.508	+2.004	+1.536	+0.722	+1.647	+1.568	+1.506	+1.557
5	Neg...	T. S. & J. D. Negus	1195	+2.058	+0.596	—0.336	—0.110	+0.328	+0.408	+0.054	+0.686	+2.022	+0.847	—0.007	—0.369	—0.118
6	Neg...	do	1317	+2.008	+1.196	+0.364	+0.540	+1.278	+0.908	+0.154	+0.936	+2.072	+1.547	+0.668	+0.356	+0.232
7	Neg...	do	1300	+2.158	+0.796	+0.064	+0.290	+1.028	+1.108	+0.454	+1.236	+2.072	+1.022	+0.268	—0.094	—0.218
8	Bd	Wm. Bond & Son	520	+3.258	+2.396	+2.064	+3.290	+3.978	+3.758	+2.754	+2.486	+3.372	+2.697	+2.543	+2.681	+2.557
9	Neg...	T. S. & J. D. Negus	1097	+0.608	—0.754	—1.986	—1.260	—0.672	—0.992	—1.546	—0.914	+0.172	—1.078	—1.507	—1.969	—1.718
10	Neg...	T. S. & J. D. Negus, S. B. C.	1536	+0.616	—0,346	—0.581	+0.697	+1.523	+1.064	+0.060	+0.291	+0.927	+0.276	—0.102	—0.091	—0.087
11	Neg...	do	1520	—0.564	—1.676	—1.931	—0.623	+0.283	—0.186	—1.290	—1.159	—0.473	—1.074	—1.402	—1.390	—1.405
12	Neg...	T. S. & J. D. Negus	1244	+1.458	+0.296	—0.536	+0.790	+1.278	+0.658	+0.204	+0.686	+1.472	+0.697	+0.118	+0.056	+0.132
13	Neg...	do	1298	+0.358	—0.804	—1.186	—0.110	+0.378	+0.008	—0.396	—0.164	+1.122	—0.853	—1.557	—1.869	—1.768
14	Neg...	do	919	—0.192	—1.404	—2.536	—2.160	—1.322	—1.592	—2.446	—1.814	—0.678	—1.478	—2.207	—2.519	—2.443
15	Neg...	do	1343	—0.542	—1.804	—2.386	—1.660	—0.822	—0.792	—1.346	—1.214	—0.028	—1.153	—1.507	—1.644	—1.618
16	Neg...	do	1059	+0.158	—0.754	—0.636	+0.490	+1.178	+0.858	—0.346	—0.464	+0.572	—0.528	—0.757	—0.769	—0.993
17	Neg...	T. S. & J. D. Negus, S. B. C.	1518	+0.536	—0.096	+0.099	+1.047	+2.063	+1.934	+0.360	+0.241	+0.727	—0.674	—0.702	—0.415	—0.588
18	Neg...	T. S. & J. D. Negus	1521	+3.208	+1.496	+0.364	+0.490	+1.028	+0.908	+0.704	+1.786	+3.372	+1.722	+0.968	+0.581	+0.782
19	Bd	Wm. Bond & Son	505	+2.608	+1.046	—0.186	+0.440	+0.878	+0.908	+0.804	+1.736	+2.822	+1.597	+0.793	+0.306	+0.632
20	Neg...	T. S. & J. D. Negus	1267	+0.808	—1.054	—1.936	—0.360	+0.428	—0.042	—0.946	—0.764	+0.472	—0.578	—1.382	—1.844	—1.743
21	Neg...	T. S. & J. D. Negus, S. B. C.	1539	+4.986	+4.374	+3.369	+4.067	+4.433	+3.864	+3.410	+4.391	+4.477	+3.651	+3.423	+3.460	+3.488
22	Neg...	T. S. & J. D. Negus	1328	+2.508	+1.196	+0.264	+0.740	+2.078	+1.708	+0.154	+1.386	+2.722	+1.097	+0.643	+0.481	+0.257
23	Bd	Wm. Bond & Son	272	—1.592	—0.954	+0.314	+1.590	+2.578	+1.958	+0.704	—0.664	—0.878	—0.928	—0.382	+0.506	—0.343
24	Neg...	T. S. & J. D. Negus	1308	+1.758	+0.946	+0.164	—0.310	+1.028	+1.508	+1.004	+1.686	+2.972	+0.972	+0.443	+0.456	+0.532
25	Neg...	T. S. & J. D. Negus, S. B. C.	1519	+1.016	—0.646	—0.181	+0.697	+1.583	+1.704	+0.410	—0.059	+1.227	+0.201	—0.227	—0.190	—0.087
26	Neg...	T. S. & J. D. Negus	1268	+1.908	+0.146	—1.486	—0.210	+0.478	+0.058	+0.054	+1.036	+2.172	+0.847	—0.382	—0.794	—0.543
27	Neg...	T. S. & J. D. Negus, S. B. C	1527	+1.016	+0.574	+1.869	+3.397	+4.483	+4.064	+2.230	+1.241	+2.507	+2.101	+2.098	+2.185	+1.664
28	Neg...	T. S. & J. D. Negus	1126	+1.008	—0.004	+0.314	+0.740	+1.128	+1.008	+0.554	+1.036	+3.622	+1.897	+0.293	+0.306	+0.207
29	Neg...	T. S. & J. D. Negus, M. T. B. C.	1255	—0.142	—1.504	—0.536	+0.590	+2.028	+1.508	+0.154	+0.486	+1.872	+0.447	—0.032	+0.206	—0.268

NOTE.—The sign + signifies a losing rate; — signifies a gaining rate. S. B. C. signifies sideral break circuit; M. T. B. C., mean time break circuit.

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Record of trial of repaired chronometers, January 9 to July 11, 1892.

[In temperature room from January 9 to March 12; after that in chronometer room.]

Relative number.	Repaired by.	Time, 1892 / Temperature / Relative humidity, per cent.		Apr. 22 to May 2.	May 2 to May 12.	May 12 to May 22.	May 22 to June 1.	June 1 to June 11.	June 11 to June 21.	June 21 to July 1.	July 1 to July 11.	Temperature of compensation.	Temperature constant.	First trial number.	Final trial number.
				67°.70	74°.77	72°.76	69°.92	78°.34	81°.32	82°.49	76°.79				
		Chronometer-maker.	*No.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	°			
1	Neg...	John Hutton	372	—0.369	—0.132	—0.355	—0.344	+0.142	+0.218	+0.350	—0.021	67.69	+0.00242	10.462	11.526
2	Neg...	T. S. & J. D. Negus	1596	+0.482	+0.543	+0.195	+0.356	+0.717	+0.543	+0.625	+0.098	66.97	+0.00281	10.421	12.854
3	Neg...	do	1036	—1.018	—0.982	—1.030	—1.069	—0.683	—0.732	—0.600	—0.827	72.59	+0.00281	12.536	13.392
4	Bl.....	John Bliss & Co	2827	+1.482	+1.293	+1.170	+1.031	+1.467	+1.093	+1.200	+0.748	70.22	—0.00222	8.356	14.961
5	Neg...	T. S. & J. D. Negus	1195	—0.193	—0.407	—0.580	—0.644	—0.533	—0.807	—0.625	—0.602	73.43	+0.00237	12.102	16.387
6	Neg...	do	1317	+0.107	—0.157	—0.330	—0.144	+0.092	+0.268	+0.575	+0.123	72.00	+0.00281	12.613	17.378
7	Neg...	do	1300	—0.418	—0.232	—0.280	—0.144	+0.142	+0.018	0.000	—0.052	71.97	+0.00264	15.686	18.230
8	Bd.....	Wm. Bond & Son	520	+2.532	+2.693	+2.420	+2.056	+3.142	+3.093	+3.325	+2.973	62.87	+0.00250	15.305	18.690
9	Neg...	T. S. & J. D. Negus	1097	—1.993	—2.232	—2.305	—2.244	—2.308	—2.382	—2.250	—2.577	71.37	+0.00347	16.984	19.015
10	Neg...	T. S. & J. D. Negus, S. B. C.	1536	—0.186	+0.075	—0.108	—0.135	+0.376	+0.553	+0.785	+0.381	64.99	+0.00303	19.438	20.001
11	Neg...	do	1520	—1.494	—1.199	—1.383	—1.511	—1.141	—0.848	—0.464	—1.070	64.51	+0.00309	19.264	20.166
12	Neg...	T. S. & J. D. Negus	1244	—0.043	+0.043	—0.155	—0.269	—0.008	—0.132	—0.125	—0.352	68.84	+0.00342	17.644	20.518
13	Neg...	do	1298	—1.868	—1.657	—1.880	—1.944	—1.383	—1.182	—1.000	—1.477	66.86	+0.00231	17.314	20.867
14	Neg...	do	919	—2.743	—2.782	—2.955	—3.044	—2.958	—3.207	—3.075	—3.477	71.32	+0.00331	17.135	21.953
15	Neg...	do	1345	—1.593	—1.257	—1.355	—1.469	—0.958	—0.657	—0.550	—0.777	67.84	+0.00220	22.524	24.149
16	Neg...	do	1059	—1.318	—1.182	—1.555	—1.994	—1.658	—1.732	—1.600	—2.227	60.75	+0.00232	15.162	25.338
17	Neg...	T. S. & J. D. Negus, S. B. C.	1518	—0.711	—0.175	—0.533	—0.710	—0.634	+0.578	+1.110	+0.381	60.28	+0.00243	17.091	26.646
18	Neg...	T. S. & J. D. Negus	1521	+0.582	+0.418	+0.195	+0.256	+0.342	+0.368	+0.500	+0.223	75.54	+0.00281	26.355	27.416
19	Bd.....	Wm. Bond & Son	505	+0.307	+0.193	+0.145	+0.106	+0.167	+0.118	+0.300	+0.023	73.70	+0.00320	25.791	27.450
20	Neg...	T. S. & J. D. Negus	1267	—2.018	—1.757	—1.855	—1.919	—1.208	—0.982	—0.550	—0.877	66.97	+0.00391	25.685	29.725
21	Neg...	T. S. & J. D. Negus, S. B. C.	1539	+3.113	+3.300	+2.942	+2.815	+3.451	+3.528	+3.810	+3.531	71.97	+0.00346	28.167	31.142
22	Neg...	T. S. & J. D. Negus	1328	+0.332	+0.593	+0.245	+0.256	+0.917	+0.968	+1.075	+0.623	70.22	+0.00463	31.799	33.830
23	Bd.....	Wm. Bond & Son	272	+0.232	+0.793	+0.620	+0.356	+1.267	+1.393	+1.500	+0.823	19.62	—0.00012	37.676	38.560
24	Neg...	T. S. & J. D. Negus	1308	+0.482	+0.643	+0.370	+0.356	+0.742	+0.618	+0.750	+0.398	77.19	+0.00165	42.547	44.996
25	Neg...	T. S. & J. D. Negus, S. B. C.	1519	—0.037	+0.225	—0.357	—0.186	+0.201	+0.128	+0.160	+0.081	51.10	+0.00137	40.045	46.320
26	Neg...	T. S. & J. D. Negus	1268	—1.068	—1.107	—1.180	—1.194	—1.358	—1.132	—0.600	—0.827	72.55	+0.00430	46.510	52.391
27	Neg...	T. S. & J. D. Negus, S. B. C.	1527	+1.637	+2.151	+1.792	+1.565	+2.051	+1.928	+2.010	+1.280	30.31	+0.00118	44.119	56.651
28	Neg...	T. S. & J. D. Negus	1126	+0.057	+0.168	+0.045	+0.056	+0.492	+0.618	+0.900	+0.623	64.81	+0.00115	47.924	71.934
29	Neg...	T. S. & J. D. Negus, M. T. B. C	1255	—0.143	+0.643	+0.295	+0.006	+0.642	+0.843	+1.050	—0.227	57.24	+0.00293	68.396	76.604

NOTE.—The sign + signifies a losing rate; — signifies a gaining rate. S. B. C. signifies sideral break circuit; M. T. B. C., mean time break circuit.

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REPORT

OF

THE SUPERINTENDENT

OF THE

U. S. NAVAL OBSERVATORY

FOR THE

YEAR ENDING JUNE 30, 1893.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1893.

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REPORT OF THE SUPERINTENDENT NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, September 28, 1893.

SIR: In compliance with the Bureau's No. 2198, dated June 17, 1893, I have the honor to submit the annual report of the United States Naval Observatory for the fiscal year ending June 30, 1893, accompanied by a duplicate set of annual estimates. (Appendix A.)

The naval officers on duty at the Observatory at the beginning of the fiscal year, July 1, 1892, were: Capt. F. V. McNair, superintendent; Commander Joshua Bishop; Lieut. Commander Walton Goodwin; Profs. William Harkness, J. R. Eastman, Edgar Frisby, S. J. Brown, and Passed Assistant Engineer A. V. Zane. Changes—reported for duty: 1892, Lieut. William H. Beehler on July 28; Lieut. L. C. Heilner on August 26; 1893, Lieut. A. G. Winterhalter (temporarily) on January 16; Lieut. C. C. Marsh April 8; Ensign A. N. Mayer March 1. Detached: 1892, Lieut. Commander Walton Goodwin on August 5; Lieut. William H. Beehler, December 14. Lieut. A. G. Winterhalter, on March 27, 1893, was assigned to special duty in charge of Naval Observatory exhibit at the World's Fair, Chicago, Ill.

On May 15, 1893, the old Naval Observatory, Twenty-third and E streets, Washington, D. C., was formally abandoned as an observatory and the new site on Georgetown Heights, Washington, D. C., officially occupied.

On October 2, 1888, a contract was awarded by the Navy Department for the erection of the buildings for a new Naval Observatory, with necessary offices for observers, stipulating that the work should be performed by April 2, 1890. This contract was extended from time to time until forfeited on September 8, 1891. After the preliminaries of inventory, valuation, and advertisement, a new contract for the completion of this work was entered into on February 16, 1892, which provided that the buildings should be finished by June 1, 1892. This time was, however, extended until February 11, 1893, when the buildings were accepted by the Government.

During the progress of the construction of these buildings contracts were made and the work performed under appropriations for the following, namely: For inclosing grounds; for bookcases, railing, shelving, standards, etc.; for transporting instruments, apparatus, piers, books, and other articles from the old to the new observatory; for repairing and remounting the great equatorial (26-inch) and its accessories, including observers' elevating platform; for repairing and remounting the meridian circle and its accessories; for repairing and remounting the transit instrument and its accessories; for repairing and remounting the prime vertical transit instrument; for furniture and gas or electric fixtures for main building, great equatorial building, clock buildings, transit houses, boiler house, and magnetic buildings; for the construction of well tank, cistern, and for purchasing and placing pump, boiler,

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ejectors, and pipes for water supply; for installation of electric plant; for standard clock; for clock-room fittings, including clocks, reflectors, piers, instruments, and all accessories, complete; for official residence of the Superintendent, and for grading, macadamizing, and guttering roads around the observatory buildings. A contract has also been awarded for a new meridian circle (6-inch objective).

Observatory lane, the entrance to the observatory grounds from the Tennallytown road, has been graded, macadamized, lighted, and a new entrance gate erected. Roads have been graded and macadamized through a large portion of the grounds, and the valley contiguous to the boiler house practically filled in; the grounds have been inclosed as authorized, and the paths partially completed. When Massachusetts avenue shall have been graded, the principal entrance to the Naval Observatory will be on that thoroughfare.

Few observations of the heavenly bodies have been made since my last annual report, as all the principal instruments were undergoing repairs. The naval officers, assistant astronomers, and computers have been engaged in supervising and inspecting instruments and their accessories while being dismounted, repaired, transferred, remounted, and adjusted; in establishing the position of the new Naval Observatory (latitude 38° 55′ 14.68″ north, longitude 5^h 08^m 15.71^s west of Greenwich), and in the reduction and preparation of the observations on hand.

Chronometers have been carefully tested for changes of temperature and rated, and together with sextants, octants, glasses, clocks, and other nautical instruments have been supplied to vessels of the Navy, as directed.

The time of noon, seventy-fifth meridian west of Greenwich, has been sent over the telegraph wires daily, without the omission of a single day, Sundays excepted, and facilities have been extended for determining the longitudes of localities throughout the United States, when requested. Inquiries having been frequently made relative to obtaining standard time from this Government Observatory, I quote the following from a memorandum to the Bureau of Equipment, dated March 12, 1892:

(1) As a Government institution the observatory diffuses the results of its observations, either directly or indirectly, as widely as practicable, among the taxpayers who support it, and therefore have the right to participate in the benefits arising from its work.

(2) The results of observations for clock corrections have been regularly given by means of telegraphic time-signals for more than a quarter of a century, without distinction or cost, to all individuals or corporations who may apply and provide the necessary apparatus for putting the signals upon their own lines.

(3) When the signals are once upon the wires it is manifestly impossible for the observatory to control either the range of their distribution or the accuracy with which they are transmitted from one circuit to another. For that reason the observatory limits its responsibility to the furnishing of an accurate daily signal at noon of the seventy-fifth meridian time. It has nothing whatever to do with the distribution of these signals and is alike indifferent to the extension or contraction of the time-service. It is for the public to decide whose time-signals they prefer and how they will obtain them.

(4) The Naval Observatory has special directions concerning the Government offices in the District of Columbia.

Prof. William Harkness, U. S. Navy, chief astronomical assistant to the superintendent, has been employed in various ways, as signified by his title, and especially engaged as inspector of the repairing and remounting of the 26-inch equatorial, the 9.6-inch equatorial, and the prime vertical transit instrument. His report is appended, marked B.

Prof. J. R. Eastman, U. S. Navy, was chief of the department of differential observations until May 10, 1893, on which date he was assigned as chief of department of fundumental observations. He was inspector

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of the repairs of both the transit circle and the 5.3-inch transit instrument, and was engaged during the severe winter of 1892–'93 in determining the longitude and latitude of the new Naval Observatory, and in reducing observations for publication. His report is appended, marked C.

Prof. Edgar Frisby, U. S. Navy, chief of departments of prime vertical observations and miscellaneous extra-meridian observations, in addition to his work in these departments, was engaged, with the assistance of Prof. Brown, in completing and preparing for publication the catalogue of stars observed by the late Capt. Gilliss, U. S. Navy. His report is appended, marked D.

Prof. S. J. Brown, U. S. Navy, has been chief of the department of differential observations since May 10, 1893, prior to which date he was given charge of other departments, owing to the lack of officers. He has been principally and diligently engaged in assisting Prof. Frisby in reducing and preparing for publication the Gilliss zone observations, made at Santiago de Chile in the years 1850, 1851, and 1852. Prof. Brown's report is appended, marked E.

Commander Joshua Bishop, U. S. Navy, chief nautical assistant to the superintendent, has, in addition to the general supervision and distribution of nautical instruments, performed the duties of general storekeeper, civil engineer, pay officer, and "captain of the yard." Commander Bishop's report is appended, marked F.

Lieut. L. C. Heilner, U. S. Navy, chief of departments of chronometers and time observations, in addition to his routine work, has been engaged in perfecting the testing room for chronometers. He was assisted in his work by Ensign A. N. Mayer, U. S. Navy, and Computer Frank E. Dennett. Lieut. Heilner's report is appended, marked G.

Lieut. C. C. Marsh, U. S. Navy, is chief of department of magnetism and meteorology. The magnetic buildings were taken apart at the old observatory and reërected at the new site. The removal of these buildings, instruments, and piers, together with their remounting and adjustment, occupied the greater part of the fiscal year. Lieut. Marsh's report is appended, marked H.

The library is under the supervision of a committee composed of Profs. William Harkness, J. R. Eastman, and Assistant Librarian Mr. William D. Horigan. Assistant Astronomer H. M. Paul performed the duties of librarian until October 15, 1892, when he was succeeded by Mr. Horigan, who has since filled the position. During the fiscal year 1892–'93 the accessions were 742, viz: 599 volumes and 143 pamphlets. Of these, 311 were received as exchanges and 431 were purchased. Upon the basis of last year's report these figures indicate that the total number of volumes in the library is now about 15,000.

The following publications were distributed to the regular exchange lists:

The Washington Observations for the year 1888.
1888 : Appendix 1—Hall (Asaph) Observations of Double Stars, 1890–'91.
1888 : Appendix 2—Hoogewerff (J. A.) Magnetic Observations, 1891.
1888 : pp. D. 1–60—Meteorological Observations, 1888.
Report of the Superintendent for 1892.

The binding for the library has been falling behind for some years, and at present there are upwards of 1,500 volumes awaiting that process. During the last year we were able to bind only 79 volumes, while the unbound volumes added to the library numbered nearly 500. In September, 1892, the library was removed to the new site. Since then the books have been reclassified and arranged in their permanent places

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on the shelves. The index numbers in the books and on the shelves are now being changed, and the work of recataloguing has begun.

A description in detail of the buildings, instruments, and grounds of the new observatory, accompanied by plates, is being prepared, and will shortly be published as an appendix to an annual volume of observations.

Very respectfully,

F. V. McNAIR,
Captain, U. S. Navy, Superintendent Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

APPENDIX B.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, September 26, 1893.

SIR: I have the honor to report that during the year ending June 30, 1893, my time has been occupied mainly by the miscellaneous duties growing out of my position as chief astronomical assistant. Respecting most of these duties it is scarcely possible to give any detailed account, because their only tangible result is to be seen in the general working of the institution. A few items may be specified as follows:

The building of the new mountings for the 12-inch and 26-inch telescopes, and the reconstruction of the prime vertical transit instrument, were effected under my supervision as inspector, and I have prepared the detailed specifications for the new 6-inch transit circle.

Starting from very small dimensions, astronomical telescopes have grown until the weight of the machinery which carries them is now reckoned in tons. So long as the parts were small it sufficed to proportion them by the eye, but when the polar axis attains the size of the screw shaft of an ordinary steamer it becomes necessary to have exact formulæ, similar to those used in the designing of steam engines. No such formulæ were available, but the Observatory library contains drawings and descriptions of nearly all the great telescopes ever made, and by a careful study of them I succeeded in making formulæ which readily give the dimensions of all the principal parts of an equatorial mounting of any possible size. The question which gave me most trouble was the determination of the proper thickness for the steel plates of the telescope tubes. No general integral can be found for the differential equations which express these thicknesses, and an expansion into series does not give sufficiently accurate results, but I finally succeeded in arranging a method by quadratures which is both simple and accurate. All the principal parts of our 12 and 26 inch equatorial mountings were designed in accordance with these formulæ, the special computations for the telescope tubes being in each case made by me, and copies of the formulæ were subsequently given to the contractors.

Into both these mountings I have introduced one feature which I believe to be entirely new, namely, a pair of dials for indicating the right ascension and declination of the point in the heavens to which the telescope is directed. A dial indicating the right ascension has been used before, but so far as I know these telescopes are the first ever provided with declination dials. Heretofore the rough setting of large equatorials has usually been effected by means of coarsely divided cir-

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cles situated, respectively, upon the polar and declination axes, but great difficulty is frequently experienced in seeing these circles at night, and in any event the hour angle of the object must be computed for setting in right ascension. With the new dials all these difficulties vanish. They face the observer when his hands are upon the right ascension and declination quick motions, they are brightly illuminated, they give the same degree of accuracy as the old-fashioned coarse circles, and as the right-ascension dial is moved by clockwork it shows the apparent right ascension of the telescope, together with its hour angle, and the right ascension of the meridian. Having the right ascension and declination of any visible object, the observer can instantly bring it into the field of the finder by setting these coördinates upon the dials; and if he wishes to set closer than that, as, for instance, in the case of a faint asteroid, he can readily do so, because the eyepieces of the microscopes for reading the fine right-ascension circle are situated at the sides of the dials, and the eyepieces of the microscopes for reading the fine-declination circle are close to the clamp and tangent screws at the eye end of the main telescope. All the movements of the instrument are controlled, and all the readings of the dials and circles are made, either from the floor of the dome or from the eye end of the main telescope, thus enabling an observer to work alone without the aid of an assistant. For greater convenience in observing the sun and moon, I have introduced supplementary gearing into the driving clock by means of which the speed of the telescope can be instantly changed from sidereal to mean solar or mean lunar. This gearing was specially computed by me, and is so exact that if the telescope is running truly on sideral time, when changed to a mean solar or mean lunar rate, the errors are, respectively, only 0.80 of a second and 1.41 seconds per day.

In planning the changes of the prime vertical instrument, my aim was to make the telescope perfectly symmetrical, and at the same time to preserve all the advantages for rapid handling which pertained to the old unsymmetrical form. This has been accomplished by giving the telescope the form of an ordinary transit instrument, and so arranging the reversing carriage that it remains permanently in place, with its machinery wholly beneath the floor. A crane and telescope have also been provided for manipulating the level. The result is that the instrument can be reversed in about fifteen seconds, and an observer standing outside of the northern pier can make all the reversals and readings of the level without moving from his place. The test of actual use has proved the new instrument to be very convenient, and it is hoped that it will give rather more accurate results than the old form.

Before beginning to draw up the specifications for the new 6-inch transit circle, I made an exhaustive study of all the descriptions of such instruments contained in the library of the observatory, and I embodied the information so obtained in a series of formulæ for the determination of the sizes of all the principal parts of transit circles. The specifications for the new instrument are based upon these formulæ, supplemented by all the information which I was able to obtain from a careful examination of some of the best modern meridian circles.

Very respectfully, etc.,

WM. HARKNESS,
Professor of Mathematics, U. S. Navy.

The SUPERINTENDENT,
United States Naval Observatory.

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APPENDIX C.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, August 23, 1893.

SIR: Since my last annual report I have been occupied with observations for the time service, with the work for determining the position of the new observatory with reference to the old observatory, and with the preparation of the complete results of the observations with the transit circle, for publication.

As soon as gas was introduced into the east transit circle room, in the autumn of 1892, observations for the time service were begun and continued until May 10, 1893.

In February, 1893, a portable transit instrument was mounted on the center of the transit circle pier at the old observatory and a similar instrument was placed on the pier in the west transit circle room at the new observatory for the purpose of finding the difference of longitude and latitude between the two positions. Sidereal break-circuit chronometers were used at each station for time, and the usual telegraphic method was utilized in the exchange of signals for the longitude work. In the latitude work the transit instruments were used as zenith telescopes. In the longitude observations the same stars were used at both stations. The same pairs of stars were used at each station in the latitude work. This method eliminated the errors in the star places from both coördinates, leaving only the accidental errors of observation and of the transmission of signals. The observers were Prof. J. R. Eastman and Assistant Astronomer A. N. Skinner. In the longitude work the observers exchanged stations and also used the apparatus to determine their absolute personal equations. In the latitude work Mr. Skinner made the observations at the old and Prof. Eastman at the new observatory. Eleven nights were devoted to observations for longitude, and latitude observations were made on three nights at the old and on four nights at the new observatory.

The difference of longitude between the adopted points of reference at the two sites was found to be $3.670^s \pm 0.012^s$, the new site being west of the old observatory. From the latitude observations the new site was found to be $1' 35.88'' \pm 0.023''$ north of the old observatory.

Assuming that the latitude and longitude, $+ 38° 53' 38.80''$ and $5^h 8^m 12.04^s$, of the old observatory were correct, this determination would give the position of the new observatory in latitude $38° 55' 14.68''$ north and in longitude $5^h 8^m 15.71^s$ west of Greenwich.

On account of the lack of assistance and the continuous use of the remodeled transit circle for time observations, it was impossible to thoroughly examine that instrument to determine the quality of the changes and repairs, and nothing was done in that direction further than to ascertain the apparently good character of the work done in redividing Circle B, and that the new 9-inch objective gave unsatisfactory star images.

On May 10, 1893, I was relieved of the charge of the transit circle and placed in charge of the department of fundamental work with one computer to assist in compiling the results of twenty-three years observations of stars with the transit circle.

The transit circle work for 1889 has been printed during the fiscal year ending June 30, 1893, and the proof of about half of the work for 1890 has been read.

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The printer's copy of the observations and results for 1891 will be finished before September 1, 1893.

Respectfully,

J. R. EASTMAN,
Professor of Mathematics, U. S. Navy.

The SUPERINTENDENT,
United States Naval Observatory.

APPENDIX D.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, September 25, 1893.

SIR: In accordance with your instructions I submit herewith the following report of the two departments under my charge:

Department of Extra-Meridian Observations.—The 9.6-inch equatorial telescope was removed from the old observatory building in December, 1892, and placed in position at the new observatory shortly afterwards. The instrument was in use during the year up to the time of its removal in the observation of comets, occultations of stars by the moon, and one partial solar eclipse. The observations made of several comets have all been reduced and published in the Astronomical Journal.

Two nights each week the public, to whom cards of admission are granted, are permitted to visit the observatory and view the heavenly bodies through this telescope.

Department of Prime-Vertical Observations.—During the winter and spring of 1892–'93 the prime vertical transit instrument was undergoing extensive repairs. It was placed in its present position in the latter part of March, 1893, and under your order of May 10 I assumed charge of it, with Computer George A. Hill as an assistant, who was promoted to assistant astronomer May 17, 1893. Mr. Hill was instructed to supervise the placing of the illuminating apparatus in position, the running of the chronograph circuit, and the other minor details necessary before observations could be taken. In June Mr. Hill determined the value of one division of the level by repeated trials with the level trier, and adjusted the instrument for level, collimation, and azimuth, and observations were made to determine the approximate latitude of the instrument; and the result, from fifteen observations of six close zenith stars, was 38° 55′ 14.7″ north. The telescope is now in complete working order, and Mr. Hill is engaged upon continuous observations of stars.

With the assistance of Prof. S. J. Brown, the catalogue of 17,000 stars observed by the late Capt. J. M. Gilliss, U. S. Navy, when stationed at Santiago de Chile, has been completed and it is now ready for publication.

Very respectfully,

EDGAR FRISBY,
Professor of Mathematics, U. S. Navy.

The SUPERINTENDENT,
United States Naval Observatory.

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APPENDIX E.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, August 25, 1893.

SIR: I have the honor to submit the following report of my work for the year ending June 30, 1893:

I was principally engaged in the reduction and preparation for publication of the Gilliss zones, made at Santiago de Chile in the years 1850, 1851, and 1852. The zone catalogue, numbering over 17,000 stars, with the exception of the introduction, was ready for the printer at the close of the year.

Owing to the detachment of nearly all the line officers on duty at the Observatory, I was in charge of the time service and east transit instrument from July 1, practically until the end of the year, assisted by Mr. George A. Hill. For the same reason I was in charge of the magnetic observatory until relieved by Lieut. Beehler, by your order, on October 1, 1892. From the beginning of the year until that time I was assisted by Computer Theo I. King. I was also given charge of the prime vertical observations made by Lieuts. C. G. Bowman and H. Taylor during the years 1881–'84, for the purpose of preparing the same for publication. A large amount of checking of their work of reduction was done by myself, assisted by Mr. Hill, but pressure of other work has so far prevented the publication of the observations.

Since May 10, 1893, I have had charge of the east transit circle, repaired and remounted. Assistant Astronomer A. N. Skinner and Computers Theo I. King and Frank B. Littell assisted in such work of investigation as was necessary to test the performance of the instrument. It was intended to take up and push to early completion the Astronomische Gesellschaft zone from 14° to 18° south declination; but as the object glass proved defective and unsuitable for the zone work, the commencement of the work is deferred until a new object glass can be procured. Many observations have been made for the determination of division errors of the circle. While incomplete, enough has been done to show that the circle is well graduated.

Computers Hill and King were my assistants in various capacities during the year, and in all practical work they were zealous and capable. Mr. King and Mr. Littell, who have been assistants to me since May 10 on the east transit circle, have shown themselves well fitted for the work of an astronomical observatory.

Very respectfully,

S. J. BROWN,
Professor of Mathematics, U. S. Navy.

The SUPERINTENDENT,
United States Naval Observatory.

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APPENDIX F.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, September 23, 1893.

SIR: I respectfully submit the following report of the department of nautical instruments for the year ending June 30, 1893:

The navigation instruments were removed from the old to the new Naval Observatory in October, 1892, and such instruments have been received from time to time, examined, and sent to vessels in commission as ordered by the Bureau of Equipment. Mr. William F. Gardner, instrument maker, has been employed in the adjustment of astronomical instruments and in wiring the buildings for electrically connecting the astronomical clocks with the different instruments; also in connecting the time-service instruments with the Western Union wires and the local circuit of wires connecting the Executive Mansion, Capitol, and the different departments for correction of time at 12 o'clock noon, seventy-fifth meridian.

The observatory was closed to visitors in October, 1892. The 9.6-inch equatorial was taken down for repairs and remounted in February, 1893; and on March 2, 1893, the observatory was again opened for visitors on Tuesday and Thursday evenings for viewing the heavens through the telescope.

Very respectfully,

JOSHUA BISHOP,
Commander, U. S. Navy.

The SUPERINTENDENT,
United States Naval Observatory.

APPENDIX G.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, August 13, 1893.

SIR: I have the honor to submit the following record of the chronometer and time service department for the year ending June 30, 1893:

The department occupied quarters at the old observatory till December 27, when the chronometers were moved to the new observatory. The transit instrument was dismounted for necessary repairs, time for the chronometers and time signals being furnished by the east transit circle.

A trial of repaired chronometers was commenced April 13, and at the end of the fiscal year was still in progess. The standard mean-time clock was mounted in the chronometer room in November, 1892, and is now performing satisfactorily. I inclose a record of chronometers received, issued, and condemned during the year.

Very respectfully,

L. C. HEILNER,
Lieutenant, U. S. Navy, in charge of Chronometer and Time Service.

The SUPERINTENDENT,
United States Naval Observatory.

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[Inclosure.]

RECORD OF CHRONOMETERS ISSUED, RECEIVED, AND CONDEMNED.

Issued to ships, 23 standards and 8 "hacks;" issued to shore stations, 7 "hacks;" issued to World's Fair, 7 standards and 1 "hack;" loaned to Smithsonian Institution, 1 standard; turned in to makers, 38 standards and 15 "hacks."

Received from ships, 35 standards and 10 "hacks;" received from shore stations, 1 standard and 6 "hacks;" received from makers, 40 standards and 15 "hacks."

Eight "hacks" have been condemned for sale; 5 "hacks" and 1 standard have been withdrawn from issue list to wait survey.

Two standards have been condemned for use as "hacks."

APPENDIX H.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, September 23, 1893.

SIR: I have the honor to submit the following report on the work done in the Magnetic Department during the year ending June 30, 1893:

As the instruments were dismounted at the old observatory and transferred to this site, along with all other instruments pertaining to the observatory, no observations or records have been taken since that time. The magnetic establishment at the old observatory was faulty in some very serious respects. The chief of these was that of regulating the temperature and moisture of the vault in which the magnetographs were mounted. The records show a range of temperature between winter and summer of more than 30° F., which range so masked the range of the magnetic elements, particularly the horizontal force and vertical force, that the reductions were only made by a most laborious process, and even when obtained were somewhat uncertain. In the buildings now about finished it is believed these faults will not exist, the vault being under ground, with double walls of brick, and air space around and above. The entrance being through a long tunnel under the main building, and the air being supplied by a long pipe extending to the ravine below, the primary sources of evil are removed. With the roof of the vault covered with cement and earth, and the heating apparatus as designed, the temperature range will doubtless be very small. The system of air supply and means of removing the moisture and controlling the temperature are briefly as follows: The air enters through a 15-inch pipe and passes through a box of broken glass, which is kept dampened with sulphuric acid, which absorbs all moisture; from thence the air passes to a small furnace with a gas stove regulated by a thermostat to the summer temperature; from the furnace the air goes by pipes to the vault and air space.

The vault has been practically finished, except the cement and earth on the roof, since the latter part of August, and the daily range of temperature has rarely exceeded 2° F.

In mounting the instruments of the magnetographs all the latest implements will be employed. The bifilar has been fitted with the best temperature compensating apparatus. The vertical force needle has been remodeled and also furnished with a new temperature bar. All needles have been subjected to an exhaustive treatment which it is hoped will render their magnetism more constant. Extensive experiments have been made to test the effect of electric lights on the instruments. The authorities at Kew, England, have been experimenting on a method of

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insulating the dynamo with which the Kew Observatory is to be supplied with electricity. Electric lights will replace the gas jets formerly used with the magnetographs.

The need of better instruments to determine the absolute values is imperative. It may be said that with the exception of the large declinometer none of the instruments are sufficiently accurate. The buildings are about ready for the instruments, which would now be mounted were it not that Mr. James, electrician, and myself have been engaged in reducing the records of 1892 in order to get them ready for the printer.

Very respectfully,

C. C. MARSH,
Lieutenant, U. S. Navy.

The SUPERINTENDENT,
United States Naval Observatory.

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[REPORT OF THE SECRETARY OF THE NAVY, 1894, pp. 164–169.]

REPORT

OF

THE SUPERINTENDENT

OF THE

U. S. NAVAL OBSERVATORY

FOR THE

YEAR ENDING JUNE 30, 1894.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1895.

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REPORT OF THE SUPERINTENDENT NAVAL OBSERVATORY.

U. S. NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, D. C., September 10, 1894.

SIR: I have the honor to submit herewith the annual report of the operations of the U. S. Naval Observatory during the year ending June 30, 1894, together with a set of estimates for the support of this establishment for the fiscal year ending June 30, 1896. (Appendix A.)

During the past year regulations for the organization and government of the Naval Observatory have been established by the Navy Department.

Lieut. A. G. Winterhalter, U. S. Navy, was detailed by the Navy Department to establish and conduct the Naval Observatory exhibit at the World's Columbian Exposition at Chicago, Ill.

26-inch equatorial telescope.—Prof. S. J. Brown, U. S. Navy, in charge Asst. Astronomer H. M. Paul, assistant.

The construction of large, complicated, and delicate equatorials is in many respects a new industry in the United States. To put this telescope in working order, and make the changes and additions inherent to the mounting and its accessories, required much care and

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thought, together with mechanical skill of a high order, and necessarily consumed a considerable amount of time.

Adjustments and changes have been made in the following parts, namely:

The filar-micrometer and the large tube.
The dial indicator on the pier and its connection to the elevating floor.
The control valves for raising and lowering the elevating platform.
The rope pulleys for rapid handling and setting of the telescope.
The adjustment of the polar axis to the plane of the meridian.
The designing of electric lamps, the entire wiring of the instrument for electric illumination and for electric control of the driving clock, and the arrangement of an observing-key for the chronograph at the eye end of the telescope.

Other minor changes have also been completed.

Some of these alterations were made by the makers; but the electric lighting, driving-clock-control and chronograph-key systems were planned and the work performed at the Observatory.

Some minute irregularities exist in the action of the driving-clock connections upon the telescope, and much time has been expended in finding their origin.

The spectroscope has been so modified that it is now readily attached and detached from the telescope.

A number of observations of Saturn's satellites have been made, and preliminary work is commenced with the spectroscope.

Prof. Asaph Hall, U. S. Navy (retired), the distinguished astronomer who discovered the satellites of Mars, has kindly consented to make further observations of them during the opposition of that planet in November next.

12-inch equatorial telescope.—Prof. Edgar Frisby, U. S. Navy, in charge.

The 12-inch object glass of this instrument is not yet made, as the appropriation for that purpose ($2,000) was not available at the close of the fiscal year. A 9.6-inch objective has, however, been temporarily fitted and used during the past year. The adjustment of this new instrument, involving minor mechanical changes, principally in the form of the micrometer, and generally getting the telescope into good working condition, including the necessary observations for finding the values of the wire intervals in right ascension and declination, and the value of the micrometer screw in seconds of arc, occupied considerable time before the instrument was regarded as satisfactory. Although a number of asteroids, and comet C, were observed prior to April, 1894, regular work with the instrument was not commenced until that date. For two nights each week this telescope has been regularly devoted to entertaining visitors; 3,200 passes were issued, and in addition, a number of distinguished persons were received at other times. On other clear nights during the months of April, May, and June comet Gale, the asteroid Germania, and an emersion of α Virginis from the moon were observed.

9-inch transit circle.—Asst. Astronomer A. N. Skinner in charge. Computers F. B. Littell and Theo I. King, assistants.

The contract for this instrument will not be completed until a proper object glass is furnished by the contractor. The present objective gives sharp definition over so small a field that observations only over the central wires are satisfactory. Considerable time was occupied in ascertaining the defects of this objective; nevertheless, pending the arrival of its substitute, work was commenced on the German Astronomical Society's zone,—13° 50′ to —18° 10′, in January, 1894. From that date to June 30, 1894, 55 zones have been observed, comprising

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4,444 zone stars and 496 zero stars. The zero stars have been reduced through zone 40. All the chronographic records of transits have been read off and the reduction of the zone stars to the mean thread commenced.

Prime vertical instrument.—Asst. Astronomer George A. Hill in charge. Observations for declination were made upon α Lyræ on all clear nights, and on μ Andromedæ, ρ Persei, θ Aurigæ, α Canum Venaticorum, and γ Boötis at the time of maximum aberration of these stars.

6-inch transit circle.—This new meridian circle was contracted for under specifications on March 20, 1893. The time for its completion is extended till March 1, 1895.

5⅛ inch meridian transit instrument, chronometer, and time service.—Lieut. L. C. Heilner, U. S. Navy, in charge. Computer Frank E. Dennett, assistant.

Observations have been taken every clear night, and the necessary reductions for clock corrections in connection with the time service and chronometer comparisons have been made.

There are at present in the chronometer room ready for issue 31 standard chronometers, 6 hacks, 3 sidereal break-circuit chronometers, and 1 mean-time break-circuit chronometer.

During the past year 35 standard chronometers, 12 hack chronometers, 7 comparing watches, 6 stop watches, and 9 maximum and minimum thermometers have been issued to naval vessels. Six standard chronometers were forwarded by the U. S. S. *Charleston* to the Mare Island navy-yard, also 6 comparing watches; 1 mean-time break-circuit chronometer was transferred to the Branch Hydrographic Office, Chicago, and 1 chronometer has been issued to the Branch Hydrographic Office, Baltimore, Md.

The Observatory has received 17 standard chronometers, 10 hacks, and 6 comparing watches from naval vessels; 1 chronometer and 7 hacks from Mare Island navy-yard; 2 chronometers from the Nautical Almanac Office; 1 chronometer (Losada, No. 3727) from the Spanish caravals at the World's Columbian Exposition, and 12 chronometers purchased after undergoing the rigid test required by specifications.

Twenty-five standards and 10 hacks have been repaired and returned to the Observatory. Twenty-seven standards and 4 hack chronometers are now undergoing repairs.

The new temperature room for the trial and testing of chronometers has proved satisfactory. The exacting and responsible routine of this department involves continuous work, both night and day, from the officer in charge and his assistant.

The time service continues to give satisfaction to the public. A time ball has been established at Chicago, and during the year requests have been received for a similar plant at other places. The noon signal has been transmitted daily with the exception of Sundays, and the apparatus for transmission of time has worked satisfactorily and without interruption. A new sidereal clock was purchased, and a mean-time clock recently constructed is now under trial.

Magnetic Observatory.—Lieut. C. C. Marsh, U. S. Navy, in charge. Occasional assistant, J. N. James, electrician.

The work in the magnetic department for the past year has been as follows: The summer and fall of 1893 were occupied in finishing the building and vault; in constructing the several piers necessary for the instruments now on hand and those that it was seen would soon be

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required; in concreting the floor of the basement and tunnel, and in laying ventilating and heating pipes, etc.

The regular observations began in January, 1894, since which time the records have been carried on continuously, losing unavoidably only a few hours.

As this is a new station it was thought best to make absolute determinations of the magnetic elements more frequently than usual, and accordingly, such determinations have been made twice a day for the declination, and four times a week for the inclination and horizontal force.

Better results are anticipated from the new instruments about to be purchased, but the appropriation for them was not available until after July 1, 1894.

Photography.—Mr. Charles T. Fellows, photographer in charge.

The photographic building and photoheliograph are not yet completed, owing to the want of funds. It is, however, contemplated that systematic observations of sun spots will be commenced shortly. In the programme of this work it is proposed to take sun photographs, daily, when practicable, and to accumulate as much data as possible for the advancement of solar physics. Photographic work with an equatorially mounted star camera will also be commenced at an early date.

LIBRARY.

The library is under the supervision of a committee composed of Prof. William Harkness, Prof. J. R. Eastman, and Assistant Librarian William D. Horigan, Mr. Horigan acting as librarian.

The contents of the library at the beginning and end of the fiscal year 1893–'94, with the accessions during the year, as shown by the accession book, were as follows:

	Volumes.	Pamphlets.	Total.
Contents 1892, June 30	14,100	3,204	17,304
Accessions during 1893–'94	396	59	455
Contents 1894, June 30	14,496	3,263	17,759

Of the 455 accessions, 263 were received as exchanges and 192 were purchased.

The following publications have been distributed to the regular exchange lists:

The Annual Report of the Superintendent for 1893.
The Washington Observations for the year 1889.
Magnetic Observations for 1892.
Meteorological Observations and Results for 1889.
1890 Appendix 1.—Gilliss's Zone Catalogue.

MISCELLANEOUS REMARKS.

The preparation of specifications for the new meridian circle (6-inch), for the 9-inch transit circle objective, for sextants, octants, binocular and spy glasses, and the inspection of nautical and astronomical instruments purchased and repaired during the year have required study, thought, and the solving of complex problems. This work, together

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with drafting many technical letters, has occupied the valuable services of Prof. William Harkness, U. S. Navy, both in and out of office hours.

The work of preparing the data for the transit circle star catalogue, embodying the results of the observations from 1866 to 1891, or in other words, all observations made with that instrument at the old Naval Observatory, excepting those of the moon and planets, has been carried on by Prof. J. R. Eastman, U. S. Navy, during the past twelve months and is now nearly completed. It is contemplated to assign this astronomer to duty in charge of fundamental observations with the new meridian circle as soon as it is mounted.

The tedious and troublesome work of reducing and preparing the Gilliss zones has been completed by Prof. Edgar Frisby, U. S. Navy, and Prof. S. J. Brown, U. S. Navy, and the catalogue is now in print.

In addition to making daily computations credit is due Computers King, Littell, and Dennett for performing night work as observers, or assistants to the astronomer in charge of the German zone observations.

Attention is invited to House Ex. Doc. No. 46, Fiftieth Congress, second session, and estimates for an appropriation for the purchase of a photographic telescope and pointer and the construction of the necessary buildings for charting the sky, are again submitted.

PERSONNEL.

Prof. Simon Newcomb, U. S. Navy, superintendent of the Nautical Almanac Office, entered the Navy in 1861 and retires in 1897.

Prof. William Harkness, U. S. Navy, entered the Navy in 1863, since which date he has been engaged in astronomical work. He retires in 1899.

Prof. J. R. Eastman, U. S. Navy, has been engaged on astronomical work since 1865, and retires in 1898.

Prof. Edgar Frisby, U. S. Navy, received his appointment in 1878, after ten years of service at the Naval Observatory. He retires from active duty in 1899.

Prof. S. J. Brown, U. S. Navy, a graduate of the Naval Academy, was appointed professor of mathematics in 1883, and has been engaged in astronomical work since that date. He retires in 1916.

The remainder of the twelve professors of mathematics, U. S. Navy, are not regarded as astronomers.

Unless, therefore, the corps of professors of mathematics, U. S. Navy, is reorganized, the Naval Observatory will in the near future have but one astronomer available for duty.

Asst. Astronomer A. N. Skinner ($2,000) has been at the Naval Observatory twenty-four consecutive years.

Asst. Astronomer H. M. Paul ($1,800) has been attached to the Naval Observatory, with intermission, sixteen years.

Asst. Astronomer George A. Hill ($1,800) was employed as computer for three years and in his present position over one year.

Computers Frank E. Dennett, Frank B. Littell, and Theo. I. King were appointed in 1891, Computer Ernest A. Boeger in 1892, and Computer William M. Brown in 1894 ($1,200 each).

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The following table presents the personnel necessary to conduct the work at the U. S. Naval Observatory:

Detail.	Line officers.	Professors of mathematics.	Assistant astronomers.	Computers.
Superintendent's office	2	1		*1
26-inch equatorial		1	1	
12-inch equatorial		1		
6-inch transit circle		1		1
9-inch transit circle		1	3	5
5⅓-inch transit instrument, chronometer and time service	2			1
Prime vertical instrument			1	
Magnetic instruments	2			
Nautical instruments and storekeeper	1			

* Also 1 clerk and 1 copyist-typewriter.

Present Observatory staff.—Capt. F. V. McNair, U. S. Navy, superintendent. Commander Joshua Bishop, U. S. Navy, assistant to superintendent. Lieut. L. C. Heilner, U. S. Navy, 5⅓-inch transit instrument, chronometer and time service. Lieut. C. C. Marsh, U. S. Navy, magnetic establishment. Prof. of Mathematics William Harkness, U. S. Navy, special duty, transit of Venus; chief astronomical assistant to the superintendent. Prof. of Mathematics J. R. Eastman, U. S. Navy, fundamental work, 6-inch meridian transit circle (under contract). Prof. of Mathematics Edgar Frisby, U. S. Navy, 12-inch equatorial telescope. Prof. of Mathematics S. J. Brown, U. S. Navy, 26-inch equatorial telescope. Asst. Astronomer A. N. Skinner, differential work, 9-inch transit circle. Asst. Astronomer H. M. Paul, assistant, 26-inch equatorial telescope. Asst. Astronomer George A. Hill, prime vertical instrument. Computers Frank B. Littell and Theo I. King, assistants, 9-inch transit circle. Computers Ernest A. Boeger and William M. Brown, computation. Computer Frank E. Dennett, assistant, 5⅓-inch transit instrument, and chronometer and time service. Clerk Thomas Harrison, correspondence and accounts. Mr. Robert H. Coker, copyist-typewriter.

Whenever there are an insufficient number of line officers on duty at the Naval Observatory competent to care for the chronometer and time service, it is manifestly imperative to assign professors, assistant astronomers, or computers for that work.

Very respectfully,

F. V. McNAIR,
Captain U. S. Navy, Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

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The following list gives the expenditures for steaming and for auxiliary purposes for each ship:

	Moving ship.	Distilling.	Pumps.	Lighting.	Heating.	Galley.	Steamboats.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Adams	367	32	.....	42	28	14	7
Alliance	121	15	2	.....	35	28	4
Amphitrite	255	53	157	44	.....	9	1
Atlanta	1,927	229	727	648	81	46	16
Alert	736	128	3	.....	111	47	29
Bancroft	144	.....	.....	.....	265	.....	.....
Baltimore	1,703	2,403 tons used for all auxiliary purposes. Details not complete.					
Bennington	1,328	180	60	626	68	50	44
Castine	509	1,079 tons used for all auxiliary purposes. Details not complete.					
Charleston	2,541	303	46	521	166	94	62
Chicago	1,719	363	681	666	30	156	108
Cincinnati	2,007	413	652	554	206	120	24
Columbia	4,815	1,094	806	1,614	280	129	54
Concord	1,563	822 tons used for all auxiliary purposes. Details not complete.					
Cushing	137	2	1	14	17	17	.....
Detroit	1,600	208	128	577	66	42	10
Dolphin	745	97	55	168	499	52	13
Essex	333	134	.....	.....	24	57	21
Fern	374	.....	4	.....	104	16	.....
Machias	935	81	89	342	30	24	23
Marblehead	1,866	199	61	427	99	36	69
Miantonomoh	354	7	28	516	16	16	16
Michigan	91	.....	.....	.....	96	40	59
Minneapolis	1,916	440	558	556	174	84	14
Mohican	625	137	.....	.....	172	67	43
Monocacy	331	97	.....	.....	174	56	8
Monterey	1,283	1,628 tons used for all auxiliary purposes. Details not complete.					
Montgomery	1,856	153	623	458	64	53	3
New York	4,014	521	662	1,576	210	87	48
Newark	1,427	468	454	575	136	173	75
Olympia	487	200	144	324	44	52	67
Petrel	643	121	17	328	132	48	1
Philadelphia	1,539	405	155	604	643	101	55
Pinta	129	24	.....	.....	179	56	.....
Raleigh	2,448	129	368	520	357	83	30
Ranger	866	138	.....	.....	46	84	28
San Francisco	2,242	189	47	672	131	204	30
Thetis	527	69	34	.....	2	46	58
Vesuvius	260	16	7	133	129	25	.....
Yantic	150	69	.....	.....	70	44	29
Yorktown	2,086	1,457 tons used for all auxiliary purposes. Details not complete.					

The Bureau during the year has reorganized the library system, the whole being based upon the best library practice of the country, which was closely studied. The Bureau has a high appreciation of the importance of this subject, and has made earnest endeavors to bring it to a high standard. The Bureau deemed it a first necessity of the subject to endeavor to cover the many sciences and arts with which the service is intimately connected, in order that officers may be given an opportunity to keep pace with their profession. While doing this it has endeavored not to lose sight of subjects of general interest, offering as wide a field as possible to the studious minds of the service.

Much time has been devoted to the subject of instruments for navigational purposes. The specifications have been perfected, and the steps taken to make a scientific inspection of instruments offered place us on an equality with the best foreign practice in this regard.

The supply of mess utensils, tableware, and table linen to the officers' messes is a very satisfactory step in a military point of view, while adding to the comfort and contentment of the service. The supply of the mess outfits to the crews has been authorized, and the Bureau is at present engaged in arranging the details and in settling upon the character of the outfit.

Much valuable information regarding the character of the coals used by the ships of the service has been obtained and will be kept up, this

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being necessary because of the change in the character of the coals from time to time sold under a particular trade name, which may cover the product of many mines.

Endeavors have been constant to mend the equipment of ships by discarding insufficient or antiquated articles and specifying for the best that can be secured. These specifications, it is expected, will make more even the purchases at the different stations, where heretofore outfits have depended much upon what was to be had in local markets, producing great variations in character and value of material supplied.

The Superintendent of the Naval Observatory reports as follows:

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, D. C., September 26, 1895.

SIR: I have the honor to submit herewith the annual report of the operations of the United States Naval Observatory for the fiscal year ending June 30, 1895.

By the "Regulations of the United States Naval Observatory," issued by the Navy Department September 20, 1894, the observatory work is divided into two branches—astronomical and nautical.

The astronomical branch includes the department of astronomical observations and the department of the Nautical Almanac.

The nautical branch includes the department of nautical instruments, the department of chronometers and time service, and the department of magnetism and meteorology.

The Astronomical Director reports as follows:

SIR: In compliance with paragraph 23 of the regulations for the government of the United States Naval Observatory, I have the honor to submit the following report concerning the operations of the astronomical department for the fiscal year ending June 30, 1895.

THE 26-INCH EQUATORIAL.

[Prof. STIMSON J. BROWN, U. S. N., in charge.]

Observations of Mars were begun on September 24, 1894, and continued until November 22, 1894, and during that period every clear night was utilized in observing the satellites and making examinations for surface markings on the planet. On the nights of October 15, 18, 19, and 24, the seeing was unusually fine. On the 19th Phobos was followed within the bluish glare of the secondary spectrum surrounding Mars, almost up to the limb of the planet, and on all these nights special efforts were made during the most favorable moments to detect some of the finer markings which have been observed by others. Powers up to 900 were used, but the best results were attained with 400 and 600. A few drawings of the planet were made, but they are noticeably lacking in the numerous canals which have been sketched with much smaller telescopes. Observations of the position angles and distances of the satellites were undertaken whenever possible, 30 being obtained on Deimos and 15 on Phobos. About the middle of November the efficiency of the telescope was somewhat impaired by moisture which collected between the two lenses composing the objective, and that, together with the increasing distance of the planet, rendered it impossible to observe the satellites after November 22. A discussion of the orbits of these satellites, based upon nearly all available material, is in progress.

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Observations of the satellites of Saturn were made from March 22 to June 18, 1895, for the purpose of accumulating data to determine the masses of the planet and ring. Except in the case of Hyperion, the observations were made by measuring the relative positions of pairs of satellites, and the number of results obtained was as follows: Iapetus-Titan, 28; Iapetus-Rhea, 23; Titan-Rhea, 6; Dione-Tethys, 25; Dione-Enceladus, 4; Hyperion, 6.

Observations of the satellite of Neptune were made from December 5, 1894, to March 21, 1895, when the unusually cold weather froze the water pipes which work the elevating platform and rendered the telescope temporarily unserviceable. Owing to the prevalance of clouds, only 14 observations were obtained.

Observations of the transit of Mercury were made on November 10, 1894; and five observations of Swift's comet, 1894, *e*, were made between December 14 and 27, 1894.

The instrument is in good order, and seems to maintain its adjustments very steadily. On account of an accumulation of moisture between its interior surfaces, the objective was removed from its cell on December 7, 1894, and the lenses were cleaned. On May 17, 1895, there was received for this telescope a much-needed set of 9 Airy-Huygenian eyepieces, and 1 Herschel solar prism, together with the necessary sun shades and adapters, all made by Mr. M. E. Kahler, and packed in a neat mahogany box. In accordance with my instructions, the equivalent focal distances of these eyepieces ranged from 0.25 inch to 4 inches, the whole forming a geometrical series whose common ratio is the square root of 2.

THE 12-INCH EQUATORIAL.

[Prof. EDGAR FRISBY, U. S. N., in charge.]

The 12-inch object glass for this instrument has not yet been completed by the contractor, and consequently the old 9.6-inch objective, which was temporarily fitted to the 12-inch mounting, is still in use. The work accomplished with it during the year was as follows: 64 observations of asteroids; 2 observations of Gale's comet; 10 observations of Encke's comet; observations of the transit of Mercury on November 10, 1894; 10 observations of occultations of stars by the moon; 6 observations of eclipses of Jupiter's satellites; and a few observations of the magnitudes and positions of variable stars.

The instrument was also used on two evenings of each week, weather permitting, for the exhibition of celestial objects to visitors. During the year 3,402 permits were issued to such visitors by the Observatory, and a large additional number were issued by the Bureau of Equipment.

Prior to May 17, 1895, this instrument had been very insufficiently supplied with eyepieces, but on that date a new set was furnished by Mr. M. E. Kahler, of this city, in accordance with specifications drawn up by me. It consists of 9 Airy-Huygenian eyepieces having equivalent foci ranging from 0.25 inch to 4 inches; 6 Kellner eyepieces (4 new and 2 old) with equivalent foci ranging from 0.25 inch to 1.414 inches; 1 Herschel solar prism, and all necessary adapters and sun shades; the whole packed in a neat mahogany case. The equivalent focal distances, both of the Airy-Huygenian and of the Kellner eyepieces, form geometrical series whose common ratio is the square root of 2.

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THE 9-INCH TRANSIT CIRCLE.

[Assistant Astronomer A. N. SKINNER in charge.]

When I became Astronomical Director I found Mr. Skinner in charge of this instrument, with Computers F. B. Littell and Theo I. King as assistants, and this very small force had been engaged since January 13, 1894, in observing the zone of stars situated between 13° 50′ and 18° 10′ of south declination for the German Astronomical Society's great international catalogue. The Observatory had undertaken to do that work so long ago as 1889, and as various causes had operated to defer its beginning until 1894, I was confronted with the problem of devising means for taking up systematic observations of the Sun, Moon, and planets, and at the same time continuing the zone work. Even under the most favorable conditions, these two classes of work would have interfered seriously with each other, but the situation was further complicated by the small number of observers at my disposal, and the best I could do was to continue Messrs. Skinner, Littell, and King upon the zone work, and to assign Assistant Astronomer H. M. Paul to the instrument for the purpose of obtaining as many observations of the Sun, Moon, and planets as he could without interrupting the zone work too seriously. Computer E. A. Boeger has also been allowed to spend most of his time in assisting Mr. Skinner.

The observations made between June 30, 1894, and June 30, 1895, are as follows: Zone stars, 8,340; zero stars, 672; American Ephemeris stars, 529; miscellaneous stars, 215; Sun, 39; Moon, 17; Mercury, 29; Venus, 25; Mars, 14; asteroids, 8; Jupiter, 5; Saturn, 6; Uranus, 8; Neptune, 1. Total, 9,908.

Respecting the zone observations, it is to be remarked that all the work at the eye end of the telescope was done by Mr. Skinner, while the pointing of the telescope, the reading of the two circle microscopes, and the recording was done either by Mr. Littell or by Mr. King, these two gentlemen acting on alternate nights. On October 5, 1894, Mr. Paul was assigned to the work of observing the Sun, Moon, and planets, but the number of observations obtained is small because there was so little clear weather that almost the whole of it was necessarily occupied by the zone work.

The webs composing the reticle in the eye end of the instrument have given much trouble by becoming so slack during damp weather that most of them had to be replaced by new ones, and many observations were lost on account of the delays thus arising.

The chronograph sheets have been read off and the transits have been reduced to the mean wire through July 15, 1895. The means of the circle microscopes have been taken and the micrometer equivalents, horizontal-wire intervals, and inclinations of wires have been applied through June 1, 1895. For the reduction of the zones the tables for refraction have been computed through zone 41 and the tables for reduction to mean place through zone 17.

In the course of the zone observations Mr. Skinner discovered two new variable stars, namely:

X Hydræ = B. D.−14°2893, $9^h\ 28^m\ 34.9^s$, −14° 02.8′ (1855).
W Ceti = B. D.−15°6531, $23^h\ 54^m\ 41.7^s$, −15° 29.5′ (1855).

These stars have also been observed by Mr. Paul, and he has determined the period of the first to be 296 days.

During the year it has been necessary to employ some rather crude devices in connection with the transit circle, partly on account of circumstances peculiar to the zone work and partly because of imperfec-

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tions in the new mounting of the instrument and its collimators, but every effort is being made to remedy these difficulties as rapidly as possible.

THE PRIME VERTICAL TRANSIT INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL in charge.]

This instrument is used exclusively for investigating variations of latitude and determining the constants of aberration and nutation. As the aperture of the telescope is sufficient to show α Lyræ in the daytime, the plan is to observe that star for variation of latitude at every possible culmination throughout the year, and to observe μ Andromedæ, α Canum Venaticorum, θ Aurigæ, and γ Bootis near the times of their maximum aberration, in order to disentangle the latter constant from the latitude variation.

The number of observations obtained during the year ending June 30, 1895, is as follows: μ Andromedæ, 30; α Canum Venaticorum, 40; θ Aurigæ, 41; α Lyræ, 126; γ Bootis, 10. Total, 247.

The webs composing the reticle in the eye end of this instrument, like those in the transit circle, have given much trouble by becoming slack and crooked in damp weather. Three separate times they have had to be renewed, and the delays thus arising have materially diminished the number of observations which would otherwise have been obtained on α Lyræ and α Canum Venaticorum.

Last November the meridian instrument Stackpole & Brother No. 1502, which is used in connection with the 40-foot photoheliograph, was mounted for the purpose of observing the transit of Mercury, and advantage was taken of that circumstance to place Mr. Hill in charge of it. It has a focal length of 30 inches, with a clear aperture of 2.55 inches, and is arranged to be used either as a transit instrument or as a zenith telescope. The magnifying power habitually employed is 61 diameters, and the micrometer has sufficient range to permit the observation of α Lyræ by Talcott's method, both as a north and as a south star. The method of procedure is to observe α Lyræ on the eastern vertical with the prime vertical transit; then on the meridian with Stackpole & Brother No. 1502, used as a zenith telescope; and finally on the western vertical with the prime vertical transit. In that way the declination of the star is determined at every observable culmination, both by the prime vertical instrument and by the zenith telescope, and thus a very complete check is obtained on the work of both instruments. Notwithstanding the small size of No. 1502, no difficulty has been experienced in observing the star in the brightest sunshine, and since November 22, 1894, a total of 93 observations have been obtained.

In justice to the observer it should be stated that the work with these two instruments is very confining, the stars coming in such a way that he has to be at the observatory for an average of about twelve hours per day.

THE TRANSIT OF MERCURY, NOVEMBER 10, 1894.

The first and second contacts of Mercury with the Sun on November 10, 1894, were observed telescopically by Prof. S. Newcomb, U. S. N., Prof. J. R. Eastman, U. S. N., Prof. Edgar Frisby, U. S. N., Prof. S. J. Brown, U. S. N., Assistant Astronomer George A. Hill, and myself; but the third and fourth contacts were unfortunately lost in clouds.

The 40-foot photoheliograph was used throughout the transit by Photographer Charles T. Fellows, Computers William M. Brown and E.

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A. Boeger, and Messrs. F. H. Parsons and F. J. Cullen, under my own immediate direction, and 131 photographs of Mercury on the Sun's disk were made, of which 129 proved excellent. These have since been completely measured by Mr. Fellows, but the measures are not yet reduced.

THE TRANSIT CIRCLE STAR CATALOGUE.

[Prof. JOHN R. EASTMAN, U. S. N., in charge.]

This catalogue will contain the mean places for 1875.0 of about 6,000 stars, based upon all the stellar observations made with the 8.5-inch Pistor & Martins transit circle while it was used at the old Naval Observatory, namely, from January 3, 1866, to June 29, 1891. In the preparation of these star places Professor Eastman has been assisted since October 12, 1894, by Mr. F. H. Parsons, temporarily employed as a computer, and since December 10, 1894, by Computer William M. Brown. The work done during the year has related principally to the computation and application of the precessions necessary for reducing the observations to the epoch 1875.0, but incidentally numerous errors in the original reductions of the individual observations have been discovered and corrected. The means of the results of observations of miscellaneous stars have not yet been taken.

Very respectfully, etc.,

WM. HARKNESS,
Professor of Mathematics, United States Navy,
Astronomical Director.

The Director of the Nautical Almanac reports as follows:

SIR: In compliance with the order of the Department of July 10 last, I have the honor to submit the following report of the work of this office for the past year:

PRINTING.

The American Nautical Almanac for 1899 and the American Ephemeris for 1898 are now in press, but copies have not yet been received. The Pacific Coaster's Almanac for 1896 is also in press. Of the Ephemeris and Nautical Almanac for 1899 104 pages are now in type.

The printing has fallen slightly in arrears, owing to the employment, with the consent of this office, of some of the printing force regularly devoted to the Ephemeris in the printing of the new tables of the planets. The introduction of the new tables, constants, and other data in the Ephemeris for 1900 involves a large amount of extra labor on the part of the regular computers, which may result in some delay in sending copy of that volume to the printer.

DISTRIBUTION.

During the fiscal year ending June 30, 1895, the sale and distribution of publications have been as follows:

Title.	Sold.	Distributed.	Public service.	Total.
American Ephemeris	547	277	550	1,374
American Nautical Almanac	1,700	.....	210	1,910
Pacific Coaster's Almanac	1,125	.....	17	1,142
Astronomical papers	5	437	15	457

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The proceeds of sales, amounting to $1,199.33, have, in compliance with law, been deposited in the Treasury to the account of the appropriation for public printing and binding.

NEW TABLES OF THE PLANETS.

Since my last annual report the discussion of the fundamental constants of astronomy, and of the elements of motion of the earth, Mercury, Venus, and Mars, has been completed and printed. The new tables of the Sun, Mercury, and Venus, based on these elements, have been brought to completion, and those of Mars nearly completed. The latter are awaiting a revision of the theory, and a new solution of the equations of condition, a work which may still require several months.

Besides the discussion of the elements and constants, the following astronomical papers were published during the last fiscal year: Volume V, Part III, Investigation of the action of the planets on the moon; Volume V, Part IV, Computation of the secular variations of the four inner planets; Volume VII, Part I, Tables of Jupiter.

The following are in press and their speedy issue is expected: Volume VI, Part I, Tables of the Sun; Volume VI, Part II, Tables of Mercury; Volume VII, Part II, Tables of Saturn.

The new tables of Venus, forming Volume VI, Part III, are now in the hands of the printer, and the composition and stereotyping are making rapid progress.

The construction of special tables of Uranus and Neptune has been postponed until the next fiscal year. This work will be easy compared with that bestowed on the other planets. When the tables are done and printed astronomers will for the first time have at hand tables of the eight major planets founded on uniform and consistent theories and data, the latter being derived from a discussion of all available observations at leading observatories of the world since 1750, as also those made on expeditions to observe the transits of Venus since 1761.

EPHEMERIS OF THE FIXED STARS.

As I have stated in previous annual reports, the most pressing need of the Ephemeris is an enlarged and improved list of those fixed stars which are used in the determination of longitudes on the earth and of the apparent positions of the heavenly bodies in the sky. For the convenience of the astronomy of the future it is desirable that a consistent list should be adopted by all the ephemerides of the world, and to avoid the necessity of frequent changes, which are always productive of confusion, it is also desirable that the list should be as accurate as possible. A desire for a uniform list, to be constructed by cooperation between the offices of different national ephemerides, has been expressed by the directors of all these publications; but no practical plan for attaining this end has yet been agreed upon. To agree upon one, a personal conference among the directors will probably be found necessary. Meanwhile work on a new list, which it is desired to introduce into the Ephemeris for 1900, has been commenced, but, owing to the absorption of the available force in the construction of the new tables of the planets, it has not made much progress.

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In addition to the formation of the proposed list of mean places, new tables for the reduction to apparent place are necessary. In the preparation of these the superintendent of the British Nautical Almanac has courteously cooperated by loaning to this office an ingenious instrument for the rapid reduction of stars to apparent place, devised by Mr. Hudson, an assistant in his office. I have had the necessary tables printed for constructing several copies of this instrument.

Very respectfully, your obedient servant,

SIMON NEWCOMB,
Professor of Mathematics, United States Navy,
Director Nautical Almanac.

DEPARTMENT OF NAUTICAL INSTRUMENTS.

[Commander JOSHUA BISHOP, U. S. N., in charge to September, 1894; Lieut. Commander WALTON GOODWIN, U. S. N., in charge October to January, 1895; Lieut. B. W. HODGES, U. S. N., in charge January 7 to June 30, 1895.]

The province of this department is to receive, inspect, and issue to the vessels of the Navy all instruments (chronometers and watches excepted) furnished for navigating and surveying purposes.

In order to put this important service upon a proper basis and to assure its systematic working whereby the best instruments can be obtained, detailed specifications have been prepared with great care for sextants, high-grade and surveying; octants; binocular glasses, day and night; quartermaster's spyglasses, high, medium, and low power; officer-of-the-deck spyglasses; barometers, mercurial and aneroid; clocks, deck and boat; three-arm protractors, and theodolites.

A complete outfit of the apparatus necessary to the thorough inspection of instruments has been provided for and will soon be installed for use.

Contractors have experienced some difficulty in fulfilling the requirements of the specifications, but better progress in that direction is now being made, and by rigidly enforcing the specifications our ships are being supplied with instruments of the above classes uniform in pattern and excellent in quality.

DEPARTMENT OF CHRONOMETERS AND TIME SERVICE.

[Lieut. L. C. HEILNER, U. S. N., in charge. Lieut. F. W. KELLOGG, U. S. N., and Computer FRANK E. DENNETT, assistants.]

The south transit instrument is used in this department for obtaining the corrections and rates of the mean time standard clock.

Observations were made for this purpose during the year whenever practicable.

The annual trial of repaired chronometers commenced December 19, 1894, and was finished May 15, 1895. Of the 25 chronometers tested, 24 had trial numbers ranging from 3.7941 to 37.9332, showing excellent performance.

During the same period 13 chronometers, submitted for purchase, were entered for competitive trial. All were rejected, the best one having a trial number in excess of the maximum allowed.

The following are the results in detail of these trials:

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Record of trial of repaired chronometers, 1894 and 1895.

Relative number.	Repaired by—	Number of chronometer.	Maker.	Dec. 19 to Dec. 26.	Dec. 27 to Jan. 3.	Jan. 4 to Jan. 11.	Jan. 12 to Jan. 19.	Jan. 20 to Jan. 27.	Jan. 28 to Feb. 4.
	Time								
	Temperature, Fahrenheit			54.98°	70.00°	85.02°	89.96°	84.99°	69.99°
	Relative humidity, per cent			70	70.7	70	70.8	70	69.2
1	Negus ..	1605	T. S. & J. D. Negus....	+0.717	+0.669	+1.133	+1.529	+1.140	+0.830
2	...do	1777	.....do.....	—0.640	—0.617	—0.760	—0.400	—0.610	—0.527
3	...do	285	Wm. Bond & Son.....	—0.783	—0.653	—0.224	+0.029	—0.253	—0.956
4	...do	863	T. S. & J. D. Negus....	+1.753	+1.383	+1.990	+2.636	+2.104	+1.187
5	...do	1449 M. T. B. C.	.....do.....	+1.039	+0.704	+1.419	+1.814	+1.461	+0.794
6	...do	1266	.....do.....	+1.431	+0.811	+1.133	+1.707	+1.211	+0.437
7	...do	1229	.....do.....	+3.074	+2.597	+3.383	+3.743	+3.069	+2.223
8	Bliss....	2829	John Bliss & Co.....	+0.539	—0.617	—0.331	—0.150	—0.324	—0.313
9	Negus ..	425	Wm. Bond & Son.....	—0.783	+0.061	+0.561	+0.743	+0.640	+0.151
10	...do	510	.....do.....	+0.610	+0.561	+1.383	+1.779	+1.069	+0.080
11	...do	1305	T. S. & J. D. Negus....	+3.110	+2.776	+3.883	+4.564	+4.140	+3.294
12	...do	1293	.....do.....	+0.646	—0.117	+0.276	+0.993	+0.640	+0.223
13	Bliss....	2860	John Bliss & Co.....	—2.069	—2.581	—1.760	—1.293	—1.324	—1.741
14	Negus ..	997	T. S. & J. D. Negus....	+2.039	+0.990	+1.383	+1.886	+1.640	+1.473
15	...do	1345	.....do.....	+2.360	+1.311	+1.454	+1.957	+1.783	+1.723
16	...do	1595	.....do.....	+2.324	+1.061	+1.633	+2.243	+1.747	+1.259
17	...do	293	Wm. Bond & Son.....	—0.069	+0.097	+1.633	+2.671	+2.033	+0.616
18	...do	1295 S.B.C.	T. S. &. J. D. Negus...	+1.384	+0.263	+1.263	+2.156	+1.453	+0.493
19	...do	1684 S.B.C.	.....do.....	+1.847	+0.226	+0.549	+1.156	+0.839	+0.637
20	...do	775	.....do.....	—0.283	—1.117	—0.760	+0.279	—0.039	—0.563
21	...do	1088	.....do.....	+1.967	+0.311	+0.061	+0.529	+0.461	+1.116
22	...do	599	.....do.....	+0.396	—0.689	—1.260	—0.543	—0.181	—0.599
23	...do	1097	.....do.....	+0.360	+0.347	+1.919	+2.957	+2.533	+1.330
24	...do	1299	.....do.....	—0.961	—1.724	—0.510	+0.850	+0.390	—0.599
25	Bliss....	504	Wm. Bond & Son.....	—0.926	—1.760	—2.510	—3.400	—2.789	—2.349

Relative number.	Repaired by—	Number of chronometer.	Maker.	Feb. 5 to Feb. 10.	Feb. 11 to Feb. 18.	Feb. 20 to Feb. 27.	Feb. 27 to Mar. 6.	Mar. 6 to Mar. 13.	Mar. 13 to Mar. 20.
	Time								
	Temperature, Fahrenheit			55.00°	45.12°	63.91°	70.05°	73.26°	69.77°
	Relative humidity, per cent			67.4	72	52.4	52	51.2	61.1
1	Negus ..	1605	T. S. & J. D. Negus.....	+0.730	+0.551	+0.137	+0.224	+0.273	+0.119
2	...do	1777	.....do.....	—0.770	—0.163	—0.827	—0.883	—0.799	—0.846
3	...do	285	Wm. Bond & Son.....	—1.020	—0.770	—1.006	—1.204	—1.191	—1.096
4	...do	863	T. S. & J. D. Negus.....	+1.630	+2.694	+1.459	+1.403	+1.487	+1.190
5	...do	1449 M. T. B. C.	.....do.....	+1.480	+2.409	+0.816	+0.724	+1.094	+0.869
6	...do	1266	.....do.....	+1.180	+2.444	+0.494	+0.260	+0.273	+0.190
7	...do	1229	.....do.....	+2.830	+3.944	+2.244	+2.331	+2.380	+2.154
8	Bliss....	2829	John Bliss & Co.....	—0.170	+1.301	—0.684	—0.919	—1.084	—1.203
9	Negus ..	425	Wm. Bond & Son.....	—0.470	—0.734	—0.220	—0.204	—0.049	—0.131
10	...do	510	.....do.....	+0.230	+0.766	—0.399	—0.383	—0.549	—0.596
11	...do	1305	T. S. & J. D. Negus.....	+3.480	+3.980	+2.887	+2.760	+2.880	+2.869
12	...do	1293	.....do.....	+1.030	+2.444	+0.260	+0.153	+0.237	+0.404
13	Bliss....	2860	John Bliss & Co.....	—1.620	—1.484	—2.149	—2.276	—2.191	—2.346
14	Negus ..	997	T. S. & J. D. Negus.....	+2.430	+3.587	+1.316	+1.153	+1.130	+1.261
15	...do	1345	.....do.....	+2.880	+4.159	+1.709	+1.224	+1.094	+1.261
16	...do	1595	.....do.....	+2.330	+3.980	+1.030	+0.760	+0.701	+0.726
17	...do	293	Wm. Bond & Son.....	+0.180	+0.444	+0.351	+0.760	+0.987	+0.904
18	...do	1295 S.B.C.	T. S. & J. D. Negus.....	+0.986	+2.534	+1.084	+0.884	+0.504	+0.921
19	...do	1684 S.B.C.	.....do.....	+1.634	+3.033	+1.263	+0.920	+0.897	+0.814
20	...do	775	.....do.....	+0.380	+1.766	—0.399	—0.597	—0.656	—0.703
21	...do	1088	.....do.....	+2.580	+4.266	+1.673	+1.046	+0.844	+1.083
22	...do	599	.....do.....	+0.680	+2.337	—1.506	—1.597	—1.084	—0.703
23	...do	1097	.....do.....	+1.430	+1.837	+1.173	+1.117	+1.166	+1.119
24	...do	1299	.....do.....	—0.220	+0.587	—1.006	—1.133	—1.191	—1.096
25	Bliss....	504	Wm. Bond & Son.....	—2.020	—2.056	—1.684	—2.240	—2.120	—2.167

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Record of trial of repaired chronometers, 1894 and 1895—Continued.

Relative number.	Repaired by—	Number of chronometer.	Maker.	Time / Temperature, Fahrenheit / Relative humidity, per cent	Mar. 20 to Mar. 27. 67.60° 66.4	Mar. 27 to Apr. 3. 71.38° 66.4	Apr. 3 to Apr. 10. 73.45° 71.2	Apr. 10 to Apr. 17. 72.82° 57.4	Apr. 17 to Apr. 24. 71.84° 66.1	Apr. 24 to May 1. 73.84° 59.3
1	Negus	1605	T. S. & J. D. Negus		+0.070	−0.036	+0.030	+0.043	+0.074	+0.120
2	do	1777	do		−0.827	−1.000	−0.934	−0.921	−0.926	−0.951
3	do	285	Wm. Bond & Son		−1.149	−1.286	−1.327	−1.493	−1.604	−1.594
4	do	863	T. S. & J. D. Negus		+1.280	+1.179	+1.351	+1.364	+1.360	+1.406
5	do	1449 M. T. B. C.	do		+0.959	+0.750	+1.066	+0.829	+0.646	+0.763
6	do	1266	do		+0.244	+0.107	+0.173	+0.221	+0.181	+0.120
7	do	1229	do		+2.173	+2.143	+2.316	+2.186	+2.289	+2.441
8	Bliss	2829	John Bliss & Co		−1.363	−1.536	−1.684	−1.636	−1.533	−1.309
9	Negus	425	Wm. Bond & Son		−0.113	−0.179	−0.041	+0.007	+0.181	+0.084
10	do	510	do		−0.756	−0.750	−0.684	−0.850	−0.890	−0.737
11	do	1305	T. S. & J. D. Negus		+2.851	+2.714	+2.744	+2.757	+2.681	+2.799
12	do	1293	do		+0.530	+0.214	+0.351	+0.543	+0.717	+0.656
13	Bliss	2860	John Bliss & Co		−2.434	−2.464	−2.506	−2.421	−2.533	−2.416
14	Negus	997	T. S. & J. D. Negus		+1.459	+1.071	+1.030	+1.150	+1.110	+1.156
15	do	1345	do		+1.173	+1.000	+0.923	+1.007	+0.824	+0.906
16	do	1595	do		+0.851	+0.750	+0.780	+0.829	+0.789	+0.763
17	do	293	Wm. Bond & Son		+0.744	+0.821	+0.923	+0.757	+0.681	+0.834
18	do	1295 S.B.C.	T. S. & J. D. Negus		+1.047	+0.981	+1.011	+1.060	+1.127	+1.211
19	do	1684 S.B.C.	do		+1.083	+0.589	+0.404	+0.417	+0.484	+0.640
20	do	775	do		−0.541	−0.929	−0.899	−0.921	−0.819	−0.951
21	do	1088	do		+1.209	+0.857	+0.780	+0.829	+0.967	+0.977
22	do	599	do		−0.970	−1.643	−1.613	−0.921	−0.854	−0.523
23	do	1097	do		+1.030	+0.929	+0.959	+0.971	+0.824	+1.013
24	do	1299	do		−1.113	−1.250	−1.149	−1.171	−1.176	−0.987
25	Bliss	504	Wm. Bond & Son		−1.827	−2.464	−2.684	−2.743	−2.711	−3.166

Relative number.	Repaired by—	Number of chronometer.	Maker.	Time / Temperature, Fahrenheit / Relative humidity, per cent	May 1 to May 8. 75.34° 68.4.	May 8 to May, 15. 75.90° 64.7.	Temperature of compensation.	Temperature, constant.	First trial number.	Final trial number.
							°			
1	Negus	1605	T. S. & J. D. Negus		+0.166	+0.286	61.415	0.0008057	3.5340	3.7941
2	do	1777	do		−1.049	−0.964	70.605	−0.000546	4.6733	5.0309
3	do	285	Wm. Bond & Son		−1.834	−1.821	59.394	0.00104	5.8198	8.5987
4	do	863	T. S. & J. D. Negus		+1.559	+1.643	67.717	0.00259	8.2527	8.8658
5	do	1449 M. T. B. C.	do		+0.809	+0.964	68.871	0.00267	8.9589	10.0910
6	do	1266	do		+0.094	+0.036	70.807	0.00273	10.3954	10.7785
7	do	1229	do		+2.309	+2.464	68.481	0.00302	11.8616	12.2337
8	Bliss	2829	John Bliss & Co		−1.263	−1.357	74.886	0.00175	10.7918	12.4022
9	Negus	425	Wm. Bond & Son		+0.059	0.000	108.774	−0.000528	12.3355	13.0614
10	do	510	do		−0.620	−0.500	63.973	0.00223	12.0176	13.4124
11	do	1305	T. S. & J. D. Negus		+2.701	+2.859	65.647	0.00274	13.7379	14.4931
12	do	1293	do		+0.630	+0.643	72.391	0.00264	13.5814	14.8901
13	Bliss	2860	John Bliss & Co		−2.584	−2.464	67.564	0.00208	14.2389	15.1547
14	Negus	997	T. S. & J. D. Negus		+0.987	+1.107	74.221	0.00285	15.4341	16.2841
15	do	1345	do		+0.951	+1.143	76.229	0.00267	16.8450	17.7211
16	do	1595	do		+0.773	+0.750	72.812	0.00377	18.4272	18.4917
17	do	293	Wm. Bond & Son		+0.951	+1.143	58.654	0.00261	18.3574	18.7917
18	do	1295 S.B.C.	T. S. & J. D. Negus		+1.114	+0.840	69.212	0.00400	18.3109	21.0433
19	do	1684 S.B.C.	do		+0.257	+0.124	74.996	0.00349	20.5684	22.9001
20	do	775	do		−0.906	−0.857	72.529	0.00295	22.0102	22.9765
21	do	1088	do		+0.809	+0.964	83.646	0.00246	24.9010	25.3688
22	do	599	do		−0.727	−0.929	78.546	0.00245	22.2733	30.1470
23	do	1097	do		+0.844	+1.000	63.077	0.00321	34.3054	36.1741
24	do	1299	do		−0.977	−0.429	67.614	0.00372	35.1909	37.9332
25	Bliss	504	Wm. Bond & Son		−3.299	−3.393	−580.922	−0.0000301	58.8914	63.8109

NOTE.—In temperature room from December 19 to February 18.
The sign + signifies losing; the sign − signifies gaining.

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Record of competitive trial of chronometers, 1894 and 1895.

Relative number.	Number of chronometer.	Maker.	Dec. 19 to Dec. 26.	Dec. 27 to Jan. 3.	Jan. 4 to Jan. 11.	Jan. 12 to Jan. 19.	Jan. 20 to Jan. 27.	Jan. 28 to Feb. 4.
		Time						
		Temperature, Fahrenheit	54.98°	70.00°	85.02°	89.96°	84 99°	69.96°
		Relative humidity, per cent	70	70.7	70	70.8	70	69.2
1	1025	H. H. Heinrich *a*	+1.431	+0.633	+0.633	+0.850	+0.676	+1.009
2	519	Wm. Bond & Son *b*	+2.289	+2.097	+2.419	+3.029	+2.533	+1.651
3	500	.....do. *b*	+0.503	+0.311	+1.311	+2 279	+0.676	—0.277
4	524	.....do. *b*	+0.289	+0.061	+1.061	+1.957	+1.319	+0.080
5	1021	H. H. Heinrich *c*	—1.211	—2.653	—3.117	—2.543	—3.074	—3.206
6	1023	.....do. *b*	+0.967	+1.419	+1.454	+2 064	+0.711	+0.009
7	995	.....do. *b*	—0.211	+0.526	+2.490	+3.350	+2.640	+1.401
8	994	.....do. *d*	+6.003	+5.561	+4.597	+4.743	+4.961	+5.687
9	1022	.....do *e*	+1.824	+0.740	+0.847	+1.529	+0.997	+0.723
10	511	Wm. Bond & Son *f*	+2.146	+3.597	+4.669	+5.529	+3.890	+2.366
11	528	.....do. *b*	+3.253	+1.454	+0.454	+1.029	+0.390	+0.401
12	990	H. H. Heinrich *b*	+2.003	+1.061	+1.169	+1.457	+0.283	—0.420
13	495	Wm. Bond & Son *b*	—0.783	—1.581	—0.653	+1.600	+1.319	+0.651

Relative number.	Number of chronometer.	Maker.	Feb. 5 to Feb. 10.	Feb. 11 to Feb. 18	Feb. 20 to Feb. 27.	Feb. 27 to Mar. 6.	Mar. 6 to Mar. 13.	Mar. 13 to Mar. 20.
		Time						
		Temperature, Fahrenheit	55°	45 12°	63.91°	70.05°	73.26°	69.77°
		Relative humidity, per cent	67.4	72	52.4	52	51.2	61.1
1	1025	H. H. Heinrich *a*	+1.980	+2.373	+1.709	+1.189	+0.773	+0.690
2	519	Wm. Bond & Son *b*	+2.080	+3.587	+1.316	+1.581	+2.344	+1.940
3	500	.....do. *b*	—0.020	+1.337	—0.501	—0.494	—0.406	—0.739
4	524	.....do. *b*	+0.980	+2.301	+0.673	+0.724	+0.701	+0.619
5	1021	H. H. Heinrich *c*	—1.620	—0.449	—2.577	—3.419	—3.656	—3.381
6	1023	.....do. *b*	+0.880	+1.480	+1.744	+1.581	+1.559	+1.047
7	995	.....do. *b*	+0.880	+1.587	+0.101	+0.117	+0.166	—0.274
8	994	.....do. *d*	+5.580	+7.194	+1.280	+1.831	+1.844	+1.119
9	1022	.....do. *e*	+2.880	+4.230	+1.887	+1.510	+1.309	+1.476
10	511	Wm. Bond & Son *f*	+1.580	+2.409	+1.566	+1.439	+1.380	+1.154
11	528	.....do. *b*	+2.230	+5.016	—0.613	—0.776	—0.870	—0.060
12	990	H. H. Heinrich *b*	+0.980	+1.944	+0.601	+0.474	+0.273	+0.083
13	495	Wm. Bond & Son *b*	+0.430	+1.944	—0.577	—0.919	—0.977	—0.774

Relative number.	Number of chronometer.	Maker.	Mar. 20 to Mar. 27.	Mar. 27 to Apr. 3.	Apr. 3 to Apr. 10.	Apr. 10 to Apr. 17.	Apr. 17 to Apr. 24.	Apr. 24 to May 1.
		Time						
		Temperature, Fahrenheit	67.60°	71.38°	73.45°	72.82°	71.84°	73.84°
		Relative humidity, per cent	66.4	66.4	71.2	57.4	66.1	59.3
1	1025	H. H. Heinrich *a*	+0.744	+0.429	+0.387	+0.257	+0.396	+0.263
2	519	Wm. Bond & Son *b*	+2.209	+2.000	+1.173	+1.079	+0.860	+0.763
3	500	.....do. *b*	—0.827	—0.750	—0.649	—0.743	—0.854	—0.666
4	524	.....do. *b*	+0.601	+0.679	+0.566	+0.650	+0.431	+0.584
5	1021	H. H. Heinrich *c*	—3.184	—3.321	—3.113	—3.136	—3.211	—3.201
6	1023	.....do. *b*	+1.173	+1.571	+1.601	+0.507	+0.931	+1.013
7	995	.....do. *b*	—0.220	+0.179	+0.566	—0.029	—0.319	+0.156
8	994	.....do. *d*	+0.673	+0.643	+1.137	+1.150	+0.789	+1.584
9	1022	.....do. *e*	+1.923	+1.536	+1.494	+1.579	+1.467	+1.334
10	511	Wm. Bond & Son *f*	+1.137	+1.071	+1.137	+1.150	+1.146	+1.156
11	528	.....do. *b*	—0.077	—0.179	—0.077	+0.114	—0.319	+0.156
12	990	H. H. Heinrich *b*	+0.030	—0.179	—0.113	+0.007	+0.146	+0.120
13	495	Wm. Bond & Son *b*	—0.149	—0.607	—0.399	—0.386	—0.640	—0.380

a Heinrich's patent auxiliary for heat and cold.
b Ordinary balance.
c Ordinary balance with auxiliary check pieces acting in heat and cold.
d Ordinary balance and reverse movement.
e Same as No. 1021, with isochronous regulator.
f Hartnup balance.

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Record of competitive trial of chronometers, 1894 and 1895—Continued.

Relative number.	Number of chronometer.	Maker.	Time	May 1 to May 8.	May 8 to May 15.	Temperature of comensation.	Temperature constant.	First trial number.	Final trial number.
			Temperature, Fahrenheit	75°.34	75°.90				
			Relative humidity, per cent	68.4	64.7				
						°			
1	1025	H. H. Heinrich *a*		+0.023	+0.214	80.967	0.00160	12.3868	16.0349
2	519	Wm. Bond & Son *b*		+0.880	+1.071	67.604	0.00203	9.4692	20.5515
3	500	.....do. *b*		−0.620	−0.643	65.302	0.00267	20.3902	21.1930
4	524	.....do. *b*		+0.344	+0.679	67.521	0.00374	20.3657	21.8663
5	1021	H. H. Heinrich *c*		−3.227	−3.107	79.349	0.00299	23.6389	25.5961
6	1023	.....do. *b*		+0.666	+0.643	67.935	0.00129	23.8933	35.5828
7	995	.....do. *b*		+0.237	+0.429	52.796	0.00216	36.1034	40.1797
8	994	.....do. *d*		+2.523	+2.857	58.774	−0.00150	23.0579	43.5516
9	1022	.....do. *e*		+1.273	+0.250	75.924	0.00402	32.7967	44.6234
10	511	Wm Bond & Son *f*		+1.273	+1.286	−30.856	0.000399	40.9728	47.0205
11	528	.....do. *b*		+0.309	+0.750	83.310	0.00290	37.1569	49.3161
12	990	H. H. Heinrich *b*		+0.201	+0.357	73.642	0.00350	53.6597	54.8918
13	495	Wm. Bond & Son *b*		−0.441	−0.429	66.472	0.00241	96.9087	101.8905

a Heinrich's patent auxiliary for heat and cold.
b Ordinary balance.
c Ordinary balance with auxiliary check pieces acting in heat and cold.
d Ordinary balance and reverse movement.
e Same as No. 1021, with isochronous regulator.
f Hartnup balance.
NOTE.—In temperature room from December 19 to February 18.
The sign + signifies losing; the sign — signifies gaining.

During the year 31 standard and 8 hack chronometers were issued, and 23 standard and 5 hack chronometers were received from ships. Three standard chronometers were condemned as such and transferred to the hack list.

Three standard and 20 hack chronometers were condemned for use and withdrawn from issue.

The operation of the time service has been entirely satisfactory, so far as transmitting the signal from the Observatory is concerned. The average error for the year of time signals sent out was 0.22^s, and the maximum resulting from changes of rate during a long period of weather unfavorable for observing was 1.29^s. The interval from July 21 to August 12 is not included in determining average and maximum error. During this time, owing to unforeseen causes (the absence of one and the sudden illness of the other officer attached to the time service), the signals were sent out by persons not fully familiar with the methods.

It must not be assumed, however, that these figures represent the errors of timekeepers that were corrected by the Observatory signals. By the methods used in repeating signals and transmitting them to long distances, over which the Observatory has no control, other errors may have crept in. Nevertheless, it may be confidently stated that these errors were rarely ever considerable, and that the time actually received was sufficiently correct for all practical purposes.

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DEPARTMENT OF MAGNETISM AND METEOROLOGY.

[Lieut. C. C. MARSH, U. S. N., in charge to June 25; Lieut. DAVID PEACOCK, U. S. N., in charge from June 25; Electrician J. N. JAMES, assistant.]

The work done in this department during the year was:

I. Perfecting, adjusting, and keeping in perfect working order the following instruments:

In the vault: 1 Kew horizontal force magnetometer; 1 Kew vertical force magnetometer; 1 Kew declination magnetometer; 1 Mascart vertical force magnetometer; 1 thermograph; 1 thermostat for regulating the gas supply; 1 polymeter (Lambrecht's).

In the observation room and office: 1 declinometer; 1 theodolite; 1 horizontal force instrument, or magnetic theodolite; 1 dip circle.

These instruments need atttention each day to see that they are in adjustment.

II. Taking observations and making experiments as follows:

(1) Deflection experiments for determining the value of a millimeter on the magnetogram scale. These experiments have to be made during the night after the electric cars have stopped running.

(2) Temperature experiments are made from time to time.

(3) Deflection experiments with the horizonal force instrument; vibration experiments and experiments for torsion with the same instrument. These experiments are made about every third day.

(4) Observations for dip with the dip circle are made about every third day.

(5) Whenever the declinometer readings show any marked change that can not be accounted for, the declination must be determined by observing a star or other heavenly body, and the theodolite and declinometer readjusted.

III. The following new instruments have been installed during the past year: 1 Mascart vertical-force magnetometer, 1 thermograph, 1 polymeter, 1 thermostat.

The Mascart vertical-force magnetometer was required, as the Kew vertical-force instrument was so delicate that it often upset during magnetic storms, thus causing the loss of the record when it was particularly needed. The new instrument is so constructed that it is almost impossible to upset it; at the same time it is more delicate in recording the changes in the vertical force. Its record agrees perfectly with the Kew instrument.

The thermograph was made from a Draper's self-recording thermometer by Lieutenants Marsh and Peacock by taking out the clock and placing a mirror on the recording arm, then placing a prismatic lens so that a ray of light is thrown on the sensitized paper of the Mascart magnetogram, thus giving a continuous record of the temperature. This, though simple, is a very valuable addition to the instruments, as the correct temperature at all times is a very important factor when experimenting with magnets.

The thermostat has worked satisfactorily in regulating the supply of gas.

IV. The records for the year ending January 16, 1895, are now in the hands of the Public Printer.

V. The following instruments have been ordered and will be installed during the present fiscal year: 1 Dr. Wild's latest magnetic theodolite or horizontal force instrument, with all the latest improvements; 1 Dr. Wild's latest improved dip circle; 1 latest improved earth inductor; 1

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balance galvanometer and telescope and scale; 1 quadrant electrometer and commutator; 1 beam suspension scale. Upon the installation of these instruments the magnetic department of the Observatory will be equal in outfit to any in the world.

The meteorological observations are made and recorded by the watchmen in the main building (Messrs. Horigan, Cahill, and Henderson).

BUILDINGS AND GROUNDS.

The attention of the Bureau has been called by a special report of Mr. William J. Marsh, architect, to the condition of the main building, and an estimate has been submitted of the cost of remedying the defects pointed out. It is important that provision for this work be made at the next session of Congress, otherwise the expense of it will be greatly increased by further deterioration. The other buildings are in good condition. Satisfactory progress has been made in grading and improving the grounds and roads.

LIBRARY.

The library has been under the supervision of a committee composed of the Director of the Nautical Almanac (Prof. S. Newcomb, U. S. N.), the Astronomical Director (Prof. William Harkness, U. S. N.), and the assistant to the Superintendent (Lieut. Commander Walton Goodwin, U. S. N.). Assistant Librarian William D. Horigan performed the duties of librarian.

The contents of the library at the beginning and end of the fiscal year 1894–95, as shown by the accession book, were as follows:

	Volumes.	Pamphlets.	Total.
Contents, 1894, July 1	14,496	3,263	17,759
Accessions during 1894–95	410	23	433
Contents, 1895, June 30	14,906	3,286	18,192

Of the 433 accessions, 162 were received as exchanges and 271 were purchased.

Very respectfully,

R. L. PHYTHIAN,
Commodore, United States Navy,
Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT.

The following is the report of the naval inspector of electric lighting:

NAVY DEPARTMENT, BUREAU OF EQUIPMENT,
Washington, D. C., September 14, 1895.

SIR: I have the honor to submit the following report of work done under the supervision of this office during the past year:

NEW SHIPS.

Work on the electric plants of new ships under construction has been continued as rapidly as the other work on them would permit. The plants of the following ships have been entirely completed, viz: The *Minneapolis*, *Olympia*, *Amphitrite*, *Maine*, *Texas*, and *Katahdin*, and those of the *Indiana*, *Massachusetts*, *Oregon*, and *Monadnock* are nearly com-

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The following list gives the expenditures for steaming and for auxiliary purposes for each ship:

Name.	Moving ship.	Distilling.	Pumps.	Lighting.	Heating.	Galley.	Steamboats.	Other.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Adams	147	56	.....	.....	29	26	18	8
Alert	600	201	1	.....	.....	47	22	.....
Alliance	181	82	1	.....	21	58	11	.....
Amphitrite	842	271	813	264	42	42	12	140
Atlanta	691	55	153	158	.....	13	3	.....
Baltimore	2,187	1,682 tons used for auxiliary purposes. Details not complete.						
Bancroft	186	218 tons used for auxiliary purposes. Details not complete.						
Bennington	455	222	63	571	138	49	42	63
Boston	1,230	178	212	464	76	48	30	21
Castine	580	345	171	248	9	34	17	70
Charleston	1,800	335	148	491	372	98	64	169
Cincinnati	988	639	384	519	216	65	63	576
Columbia	2,904	1,071	933	1,838	560	131	55	92
Concord	823	1,035 tons used for auxiliary purposes. Details not stated.						
Cushing	84	21 tons used for auxiliary purposes. Details not stated.						
Detroit	1,009	422	250	613	69	49	15	.....
Dolphin	988	104	76	222	197	54	62	365
Essex	252	110	.....	.....	90	50	14	.....
Fern	177	.....	4	.....	69	4	.....	43
Indiana	1,094	1,718 tons used for auxiliary purposes. Details not complete.						
Katahdin	248	28	23	143	28	12	.....	62
Lancaster	511	193	32	4	47	69	31	.....
Machias	371	108	116	490	86	33	30	.....
Maine	770	173	061	650	110	82	51	61
Marblehead	1,104	159	52	667	67	47	121	389
Marion	681	166	63	.....	.....	33	19	60
Michigan	289	.....	.....	.....	90	42	14	.....
Minneapolis	5,013	569	553	1,142	137	147	50	577
Mohican	127	43	.....	.....	56	10	13	.....
Massachusetts	133 tons used for all purposes. Details not complete.							
Monocacy	360	93	2	.....	146	64	15	.....
Monadnock	245	65	86	334	17	21	22	72
Monterey	874	209	209	750	189	59	26	29
Montgomery	1,285	191	796	527	132	65	41	.....
Newark	2,579	398	758	758	30	97	71	.....
New York	3,103	729	1,093	2,035	313	96	120	157
Olympia	3,075	1,084	301	1,048	45	111	98	49
Petrel	697	475 tons used for auxiliary purposes. Details not complete.						
Philadelphia	764	2,324 tons used for auxiliary purposes. Details not complete.						
Pinta	90	24	.....	.....	212	70	.....	.....
Raleigh	2,957	252	312	716	.....	122	53	351
Ranger	237	60	.....	.....	21	33	18	22
San Francisco	1,998	305	163	619	106	213	50	4
Terror	380 tons used for all purposes. Details not complete.							
Texas	423	1,125 tons used for auxiliary purposes. Details not complete.						
Thetis	616	59	40	.....	11	43	55	.....
Yantic	95	87	1	.....	72	41	36	.....
Yorktown	510	296	203	410	106	124	20	.....

The Bureau, in endeavoring to utilize American coal as much as possible, has made a trial of placing a cargo of Pocahontas coal at Honolulu. This has been done at a rate which allows it to compete successfully with the Dominion of Canada coal, or that from Australia.

It is of first importance that we should use good coal, particularly on the more distant stations and at ports where coaling points are distant. The reasons are many and obvious, among them being the greater steaming radius, and a thus practically greater bunker capacity; a greater efficiency in motive power, less damage to boilers, and less labor on the part of firemen and coal passers.

During the year the mess outfits have been extended to the enlisted men with very satisfactory results.

Homing pigeon stations have been established at Newport, R. I., New York, Norfolk, Va., Key West, Fla., and Mare Island, Cal., and preparations made for a station at Portsmouth, N. H. The period has been too short to do much actual work, but the whole is on a very satisfactory basis for future use.

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The following is the report of the Superintendent of the Naval Observatory.

UNITED STATES NAVAL OBSERVATORY,
GEORGETOWN HEIGHTS,
Washington, D. C., August 29, 1896.

SIR: I have the honor to submit the annual report of the operations of the United States Naval Observatory for the fiscal year ending June 30, 1896.

ASSISTANT TO THE SUPERINTENDENT.

In addition to the duties of this office, detailed in the Regulations for the Government of the Naval Observatory, the Assistant Superintendent is the equipment officer and general storekeeper of the station. The latter duty embraces the preparation of the transfer papers of all articles issued, making the weekly and monthly reports incident to the general storekeeper's office, and keeping all books of record. This very considerable amount of work has been done by Lieut. Commander Walton Goodwin, United States Navy, without clerical aid.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

Professor William Harkness, United States Navy, the Astronomical Director, reports as follows concerning the work of this department:

THE 26 INCH EQUATORIAL.

[Professor STIMSON J. BROWN, U. S. N., in charge.]

As usual this telescope has been principally employed on work which could not well be done with smaller instruments, but on account of the abnormal prevalence of cloudy weather, the number of observations obtained is somewhat below the average. They are as follows: Swift's comet, (*a*) 1895, 14; Faye's comet, 10; Polyhymnia, 5; Titan-Iapetus, 26; Dione-Tethys, 22; Dione-Enkeladus, 3; observations of double stars, 17; occultations of stars by the moon, 2.

During the early twilight hours in the month of March, search was made for the companion of Sirius on every favorable opportunity, and on one or two occasions what seemed to be faint objects were measured, but it is not certain that they represent anything really existing in the heavens. There was indeed little reason to expect that the search would be successful, because the computed distance of the companion from Sirius was then between 3.5″ and 4.2″, and in 1889 Professor Hall found that, althougn it remained visible in this telescope when its distance had decreased below 5.8″, it was then too difficult to measure.

During the period from January to March, many attempts were made to observe Jupiter's fifth satellite, but they all resulted in failure, although Professor Brown had found it a comparatively easy object at the old observatory in 1892. Attempts were also made at various times during the year to reobserve some of the most important of the close double stars which were measured by Professor Hall at the old observatory. The greater part of these objects require magnifying powers of from 600 to 900 diameters, but no nights were found during the winter when such high powers could be used. Generally 400 was too high for good definition, and often even 200 was impracticable. Professor Brown

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thinks that in the cold weather the seeing with the 26-inch telescope was worse here than at the old observatory, and that the difference should not be ascribed wholly to the unfavorable conditions which prevailed during last year. The construction of the equatoral building is defective, in that the office rooms, which are necessarily warmed in winter, are separated from the telescope room only by an ordinary door without any intervening passageway, the heavy masonry walls give rise to much radiation, and the temperature in the basement under the elevating floor is frequently 10° higher than in the dome above. Under these circumstances the warm air in the basement finds a ready escape into the telescope room through the various necessary openings in the elevating floor, and thus renders good definition impossible. The consequent loss of work has been a source of much vexation.

Some time was spent in adjusting the spectroscope to the photographic focus of the $H\gamma$ rays from Sirius. Two successful photographs were obtained with exposures of 45 minutes, but owing to the difficulty of keeping the H rays on the slit, only about one-third of that time was effective. The image given by these rays was fairly visible, and the difficulty in maintaining the pointing arose from the fact that the right ascension slow motion screw of the telescope is at an inconvenient distance from the spectroscope, and does not give a sufficiently delicate motion for this special purpose.

The observations of miscellaneous objects have been prepared for publication, and the systematic work on the satellites of Mars and Saturn has been partially discussed. In the case of Phobos all the observations made with the Lick 36-inch telescope have been reduced and incorporated with our own. Thus far the reduction of the work on the satellites of Saturn has been confined to Titan-Iapetus, and all equations of condition for the observations of 1894–95 have been completed, but they still need checking.

Professor Brown was absent from the Observatory on a trip to Europe from July 20 to November 12, 1895, and during that period the 26-inch telescope was used by Professor Frisby for the observation of such objects as were too faint to be readily seen with the 12-inch telescope.

The dome covering this instrument is turned by means of a hand-rope whose motion was originally ten times that of the circumference of the dome. The diameter of the dome being 45 feet, in order to turn it half around the rope had to be pulled through 706 feet, and, notwithstanding the lightness of the motion, that was very tiresome. On June 22, 1896, Messrs. Warner & Swasey altered the gearing connecting the rope with the dome, so as to make the speed of the former only five times that of the latter; and, although the average pull was thereby increased to about 19 pounds, the labor of turning the dome has been rendered much less exhausting.

The following alterations in the mounting of the 26-inch telescope were also made by Messrs. Warner & Swasey toward the end of June, 1896. First, the latitude adjustment of the polar axis having been quite exhausted in the original adjustment of the instrument, a steel plate 0.125 of an inch thick was inserted under the northern adjusting wedge, so as to bring the adjusting screws back to the middle of their run; second, a pair of magnets were applied to the driving clock of the telescope for the purpose of supplying an electrical control from one of the standard sidereal clocks. It is doubtful if any advantage will result from this, but it was thought desirable to try the experiment.

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THE 12-INCH EQUATORIAL.

[Professor EDGAR FRISBY, U. S. N., in charge.]

The old 9.6-inch Munich objective continued to be used in this telescope until December 19, 1895, when it was replaced by a new 12-inch objective made by Messrs. Alvan Clark & Sons, of Cambridgeport, Mass. The latter is as nearly as possible of the Fraunhofer-Herschel form, its curves having been specially computed by the Astronomical Director from the refractive indexes of the hard crown and dense flint glasses out of which its lenses were made. Of course the use of a new objective necessitated a new determination of the intervals of the micrometer wires, and of the value of a revolution of the micrometer screw, and five nights were spent in that work.

The observations made during the year were as follows: Parthenope, 1; Polyhymnia, 2; Pales, 1; Clio, 1; Undina, 1; Hermione, 1; Perine's comet, 5; Comet (*a*), 1896, 10; Comet (*b*), 1896, 8; observations of four faint comparison stars, 8; occultations of stars by the moon, 40; eclipses of Jupiter's satellites, 11.

On account of the unusual amount of cloudiness, much time was fruitlessly spent in looking for faint objects during unfavorable weather.

All observations are reduced up to date, and those requiring prompt publication have been printed in the Astronomical Journal. In addition to this, Professor Frisby has found time to compute the reduction from apparent to mean place for a considerable number of zone stars, and an ephemeris of the risings and settings of the moon at Washington for the entire year.

On two evenings of each week, weather permitting, the 12-inch telescope has been used for the exhibition of celestial objects to visitors. During the year 2,759 permits were issued to such visitors by the Observatory, and a large additional number were issued by the Bureau of Equipment.

THE 9.14-INCH TRANSIT CIRCLE.

[Assistant Astronomer AARON N. SKINNER in charge.]

In the work of this instrument Assistant Astronomer Skinner has been aided during the year by Assistant Astronomer H. M. Paul, Computers Frank B. Littell, Theo I. King, and E. A. Boeger, and since October 8, 1895, he has also had the services of Mr. John N. James for a large part of the time, that gentleman having acted as a computer whenever he was not occupied by his duties as electrician.

The observations made during the year were as follows: Zone stars situated between 13° 50′ and 18° 10′ of south declination, 4,897; Zero stars, 390; American Ephemeris stars, 778; miscellaneous stars, 44; Sun, 63; Moon, 37; Mercury, 38; Venus, 56; Jupiter, 9; Saturn, 1; Uranus, 1; Neptune, 11. Total, 6,325.

The original observing list for the German Astronomical Society's Zone, lying between 13° 50′ and 18° 10′ of south declination, contained 8,689 stars, and the plan of operations undertaken by this Observatory required that each of these stars should be observed twice with the meridian circle, viz, once with clamp east and once with clamp west. Accordingly, the instrument was used with clamp east during the calendar year 1894, and with clamp west in 1895, and the work was substantially completed on January 4, 1896. Probably two or three hundred additional observations will yet be required to supply accidental omissions and clear up discordances.

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In the progress of the zone observations Mr. Skinner has discovered two more new variable stars besides the two mentioned in my last report. Mr. Paul has regularly observed all four of these variables during the year, as well as one or two others suspected by Mr. Skinner, but not yet shown to be variable. The numbers and names assigned by Dr. Chandler in his catalogue to the four new variables, their Bonn Durchmusterung numbers, and the number of nights each has been observed during the year are as follows:

3,425	X Hydræ	=BD −14°2893	16 nights.
5,405	RT Libræ	=BD −18°3975	24 nights.
7,590	Z Capricorni	=BD −16°5811	23 nights.
8,622	W Ceti	=BD −15°6531	29 nights.

For the two variables first discovered, X Hydræ and W Ceti, Mr. Paul has determined and published approximate elements of variation; but for the other two, further observations are necessary to decide between several possible periods.

The small number of observations of the Sun, Moon, and planets is due partly to the circumstance that the instrument was undergoing repairs for almost five months, and partly to the unusual prevalence of clouds, which compelled us to use most of the clear nights on the zones in order to prevent them from extending over another year.

The state of the reductions is as follows: For the zone stars, the tables for the reduction from apparent to mean place are nearly completed, and about 5 per cent of the reductions in right ascension have been applied; the corrections for level, collimation, and azimuth have been applied throughout; about 11 per cent of the clock corrections have been applied, and about 33 per cent of the refractions. The Sun, Moon, and planet observations are all copied on the reduction sheets.

In compliance with special requests, the moon observations from March 1 to October 1, 1895, have been reduced for the Zi-ka-wei Observatory in China; 20 observations of 10 zone stars have been reduced for Professor Lorenzoni, of Padua, Italy; and 2 observations of 1 zone star have been reduced for Professor Schur, of Göttingen, Germany.

During the year the transit circle has undergone three very important alterations. (1) A new cell has been made for the object glass, and a new mounting has been provided for carrying the sliding tube at the eye end of the telescope. (2) The old collimator piers have been replaced by larger ones, and more substantial mountings have been provided for carrying the collimator telescopes and the long focus lens used in viewing the meridian mark. (3) Suitable shades have been provided for protecting the transit circle from the direct rays of the sun while that body is being observed.

As originally constructed by Pistor & Martins, the telescope of the transit circle had a clear aperture of 8.52 inches and a focal distance of 145 inches. When the instrument was removed from the old to the new Observatory it was thought desirable to shorten the telescope, and accordingly a new objective of 9.14 inches clear aperture and 108 inches focal distance was provided. This necessitated a complete reconstruction of the objective and eye ends of the telescope tube, and the work was intrusted to a Washington firm of high reputation, but when tested by actual use it proved to be so badly done that the stability of the line of collimation was open to doubt. The zone observations could not well be interrupted, but as soon as they were finished it was decided to attempt to remedy this very serious defect, and in a consultation between Mr. Swasey and the Astronomical Director, the changes to be made were

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agreed upon, and Mr. Swasey declared that the time necessary to effect them would not exceed four working days in the shops of his firm. On January 28 the instrument was dismounted in the confident expectation that it would not be out of use more than two weeks, but when the parts to be altered were taken to pieces and examined it became evident that the proposed alterations were impracticable, and that the only satisfactory course would be to make entirely new mountings for both the objective and eye ends of the telescope. Detailed drawings and specifications for the new parts were prepared by the Astronomical Director, and the work was put into the hands of Messrs. Warner & Swasey as expeditiously as possible, but notwithstanding the most strenuous efforts, the end of May had nearly arrived before the instrument was again put together.

The piers and mountings of the transit-circle collimators and long-focus lens for the meridian mark were furnished by the firm who altered the telescope, and they also proved so unstable that contracts for replacing them with larger piers and better mountings were given to Messrs. Warner & Swasey in 1894 and 1895. Various delays occurred, in consequence of which the collimator telescopes were in the shops of the contractors during the month of May, 1896, and the new piers were not in place until the middle of June. While the new mountings were being fixed on the piers, the shades for protecting the transit circle from the sun's rays were put in place, and the whole work was completed on June 27, 1896. Observing was resumed on June 28, the anticipated interruption of two weeks having extended to five months.

THE PRIME VERTICAL TRANSIT INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL in charge.]

This instrument is used exclusively for investigating variations of latitude and determining the constants of aberration and nutation. As the aperture of the telescope is sufficient to show α Lyræ in the daytime, the plan is to observe that star for variation of latitude at every possible culmination throughout the year, and to observe μ Andromedæ, α Canum Venaticorum, θ Aurigæ and γ Bootis near the times of their maximum aberration in order to disentangle the latter constant from the latitude variation. Furthermore, α Lyræ is also observed at every possible culmination with the meridian instrument Stackpole & Bro. No. 1502, the method of procedure being to observe the star on the eastern vertical with the prime vertical transit, then on the meridian with Stackpole 1502 used as a zenith telescope, and finally on the western vertical with the prime vertical transit. In that way the declination of the star is determined at every observable culmination both with the prime vertical transit instrument and with the zenith telescope, and thus a very complete check is obtained on the work of the two instruments.

The number of observations obtained during the year was as follows: With the prime vertical transit instrument, μ Andromedæ, 15; θ Aurigæ, 45; α Canum Venaticorum, 34; α Lyræ, 130. With the zenith telescope, α Lyræ, 150. Total, 374 observations, in getting which the observer was obliged to spend the entire night at the Observatory 151 times.

All observations made with the prime vertical transit instrument and zenith telescope prior to April 21, 1896, have been reduced, and all made with the former instrument prior to January 1, 1896, have been copied upon sheets for the printer. During intervals not occupied by

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his regular duties as photographer, Mr. Charles T. Fellows has given Mr. Hill much valuable clerical assistance.

In December and January a redetermination of the constant of the micrometer screw of the zenith telescope was made by observing the stars 17, 19, 23, η, 27, and 28 Tauri on 18 nights; the result being, one revolution of the screw $= 68.455'' \pm 0.0028''$.

The Washington firm who altered the 9.14-inch transit circle also altered the prime vertical transit instrument at the time of its removal from the old to the new Observatory, and in many respects their work upon the latter instrument has ultimately proved almost as unsatisfactory as that upon the former. One of the most vexatious defects was the extreme difficulty of reading the bubble of the striding level through the small Galilean telescope provided for that purpose on top of the northern pier. This has been remedied by substituting an inverting telescope, with a Huyghenian eyepiece magnifynig six diameters, in place of the Galilean one; and by removing the protecting glass tube which surrounded the bubble tube, and substituting in its place a glass box with perpendicular sides, containing a photographed scale standing over the bubble tube perpendicularly to the line of sight and showing bright lines on a dark ground. These alterations were made in August, 1895, by Mr. M. Kahler, of this city.

THE TRANSIT-CIRCLE STAR CATALOGUE.

[Professor JOHN R. EASTMAN, U. S. N., in charge.]

This catalogue will contain the mean places for 1875.0 of about 6,000 stars, based upon all the stellar observations made with the 8.5-inch Pistor & Martins transit circle at the old Naval Observatory. In its preparation Professor Eastman has been assisted during the year by Computer William M. Brown, and by Mr. F. H. Parsons, temporarily employed for this purpose. The time of these gentlemen has been occupied in taking the means of the annual results for the places of the miscellaneous stars, computing the precessions of the Ephemeris stars, and computing the secular variations of the precessions for both the Ephemeris and miscellaneous stars. The annual results for the positions of the Ephemeris stars, together with the catalogue based upon them, are ready for the printer.

MISCELLANEOUS MATTERS.

In October, 1895, the Observatory received a new comet seeker, made by Mr. John A. Brashear, of Allegheny, Pa. Its telescope has a clear aperture of 5.0 inches with a focal distance of 40 inches, and is of the bent form, with alt-azimuth mounting. The place for the observer's eye is at the extremity of the horizontal axis, and there are 5 Huyghenian eyepieces whose magnifying powers were intended to be respectively 20, 28, 40, 57, and 80 diameters.

The observing houses for the east and west transit circles, and for the prime vertical transit instrument, are all lined with corrugated sheet zinc 0.031 of an inch thick. The sheets composing the ceilings were bent to a large radius and set between the iron rafters in such a way as to form flat arches which were perfectly secure so long as the metal retained its form; but, unfortunately, zinc is very easily affected by heat, and under the action of our high summer temperatures the sheets gradually buckled, and finally began to give way. To remedy this the ceilings of the three observing houses in question were taken down

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during March and April of the present year, and the zinc sheets were first straightened, and then replaced in a more substantial manner.

Since leaving the old Observatory much inconvenience has been experienced for want of a support suitable for carrying level triers, and other small apparatus, requiring great stability. Toward the end of last June this need was supplied by the erection in the clock house of a slate table 18 inches wide and 56.5 inches long, supported upon two small brick piers.

It is a matter of regret that very little progress has been made with our printing during the present year. Early in the fall of 1895 the Observatory volume for 1890 was completely set up and stereotyped, and in response to all subsequent inquiries we have been told that the work was being prosecuted as rapidly as other demands upon the Government Printing Office would admit. I understand that the presswork is finished, but the volume is not yet bound.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics United States Navy,
Astronomical Director.

Referring to Professor Harkness's remarks upon the defective construction of the equatorial building, from which results imperfect seeing with the 26-inch equatorial during very cold weather, the defects are remediable, in part at least, and steps are now being taken to apply such remedies as are practicable.

These remedies will consist in walling up the opening between the basement of the dome and of the offices, and of fitting double doors to all lines of communication on the main floor between the dome and the office building.

DEPARTMENT OF THE NAUTICAL ALMANAC.

Professor Simon Newcomb, United States Navy, the Director of the Nautical Almanac, having been detailed by the Navy Department as a member of the Paris Conference on Astronomical Constants and of the International Conference on Scientific Literature, has been absent on these special duties since April 15, 1896.

During his absence Professor William W. Hendrickson, United States Navy, has performed the duties of his office. Professor Hendrickson submits the following report of the work of the department of the Nautical Almanac:

PRINTING.

The American Nautical Almanac for 1899 has been published, and the American Ephemeris for 1899 is in press. The Pacific Coaster's Nautical Almanac for 1897 is also in press. The printing of the American Nautical Almanac for 1900 has been commenced.

DISTRIBUTION.

During the fiscal year ending June 30, 1896, the sale and distribution of publications has been as follows:

Title.	Sold.	Distributed.	Public service.	Total.
American Ephemeris	524	651	487	1,662
American Nautical Almanac	2,149	.....	273	2,422
Pacific Coaster's Almanac	1,242	.....	23	1,265
Astronomical Papers	2	881	5	888

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The proceeds of sales, amounting to $1,020.24, have, in compliance with law, been deposited in the Treasury to the account of the appropriation for public printing and binding.

NEW TABLES OF THE PLANETS.

Since the last annual report the following have been published: Volume V, Part V, The Mass of Jupiter and the Orbit of Polyhymnia; Volume VI, Part I, Tables of the Sun; Volume VI, Part II, Tables of Mercury; Volume VI, Part III, Tables of Venus; Volume VII, Part II, Tables of Saturn.

The revision of the theory necessary to the completion of the tables of Mars is still in progress. Work has been commenced on the tables of Uranus and Neptune.

EPHEMERIS OF FIXED STARS.

Since January all the available force of the office has been employed upon the new catalogue of standard stars and in preparing the tables necessary for the ephemeris of apparent places of these stars for use in the American Ephemeris and Nautical Almanac for 1900 and succeeding volumes.

The office has sustained a serious loss in the death of Assistant Cleveland Keith, whose talent for astronomical work was far above the official position he held.

Very respectfully,

W. W. HENDRICKSON,
Professor U. S. Navy, in charge of Office.

DEPARTMENT OF NAUTICAL INSTRUMENTS.

Lieutenant Frank W. Kellogg, United States Navy, was the head of this department.

The classes of nautical instruments issued from the Observatory are: Sextants, octants, spy glasses, binocular glasses, protractors, stadimeters, drawing instruments, reading glasses, theodolites, measuring tapes, plane tables, physchrometers, thermometers, barometers, surveyors' compasses and chains, deck and boat clocks, clinometers, photographic outfits, parallel rulers, and other instruments issued to ships for navigating and surveying purposes.

Sextants and octants are inspected for accuracy of dimensions, form and fit of the pivot, graduations of arc and vernier, eccentricity of limb, optical performance of telescopes, parallelism of faces of mirrors and shade glasses, weight, quality of workmanship, and conformity in other respects to the specifications.

Spyglasses and binoculars are inspected for power, field, clear aperture, focal distance, and mechanical construction, as set forth in the specifications for the several grades of glasses.

Other instruments are inspected for conformity to detailed specifications that are attached to the requisitions for them.

The work of this department is laborious, requiring patience and painstaking.

The rigid inspection of nautical instruments under carefully prepared specifications, as now conducted, has been productive of the good results that were anticipated, and it may be confidently asserted that our ships are being supplied with instruments well adapted to their uses and at

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reasonable cost, the latter being largely due to the wide range of competition that has been invited.

The value of this department of the Observatory to the naval service can not be overestimated.

In addition to the above routine work, a number of devices submitted by inventors and others have been examined and reported upon with such recommendations as were deemed proper in each case.

DEPARTMENT OF CHRONOMETERS AND TIME SERVICE.

Lieutenant L. C. Heilner, United States Navy, was the head of this department until August 12, 1895, when he was succeeded by Lieutenant William V. Bronaugh, United States Navy. Lieutenant Bronaugh reports as follows:

The following is the disposition of the chronometers belonging to the Navy:

Kind.	In service afloat.	In service on shore.	In store at Mare Island.	At Observatory for issue.	Undergoing repairs.	Awaiting repairs.	For survey.
Standards	127	13	34	25	13	.....	.....
Hacks	41	23	11	3	3	4	1
M. T. B. C	.....	4	1	2	.....	.....	.....
Sidereal, B. C	1	4	2	1	3	.....	.....
Sidereal	.....	.....	1	1	.....	.....	.....
Pocket	.....	.....	.....	5	.....	.....	.....

In addition to the above there are in store 14 comparing watches for issue, 1 for repairs, and 1 for survey; 14 silver-case stop watches and 2 gold-case stop watches for issue; 10 maximum and minimum thermometers for issue and 4 in use at Observatory.

One standard chronometor has been condemned and transferred to the hack list, leaving a total of 212 standards. Of these, 95 are over thirty-five years old, and the probabilities are that they will soon cease to be reliable as timekeepers.

During the year 22 standard chronometors, 10 hacks, 7 stop watches, 8 comparing watches, and 7 maximum and minimum thermometers have been issued to naval vessels, and 5 stop watches, 6 comparing watches, and 6 maximum and minimum thermometers have been sent to the Mare Island Yard for issue. The Observatory has received 12 standards, 5 hacks, 1 stop watch, and 2 comparing watches from naval vessels; 4 hacks from Mare Island Yard; 2 comparing watches and 2 maximum and minimum thermometers from other Navy Yards. One standard chronometer loaned to Lieutenant Beehler has been returned, and 1 mean-time break-circuit chronometer and 1 maximum and minimum thermometer, issued for use in connection with Naval Exhibit at the Atlanta (Ga.) Exposition, were returned.

Eight maximum and minimum thermometers condemned by survey as worthless have been expended; 2 comparing watches and 1 stop watch condemned by survey were sent to the New York Navy-Yard for sale.

The annual trial of repaired chronometers commenced December 14, 1895, and was finished May 24, 1896. Twenty-one standard chronometers and 1 mean-time break-circuit chronometer were subjected to trial. During the same period 21 chronometers submitted for purchase were subjected to trial, and 2 chronometric thermometers entered at the same time are still undergoing trial. The results in detail of the trials are:

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Record of trial of repaired chronometers (December, 1895, to May, 1896).

[In temperature room from December 14, 1895, to February 28, 1896; after that in chronometer room.]

Relative number.	Repaired by—	Chronometer number.	Maker.	Time	Dec. 14 to Dec. 21.	Dec. 22 to Dec. 29.	Jan. 4 to Jan. 11.	Jan. 13 to Jan. 18.	Jan. 20 to Jan. 27.	Jan. 28 to Feb. 4.
				Temperature, Fahrenheit	46.22°	54.95°	70.00°	85.11°	89.99°	84.94°
				Relative humidity, per cent	68.6	68.1	69.6	68.8	69.5	68.8
1	Negus	1783	T. S. & J. D. Negus		+1.263	+1.034	+1.104	+0.912	+1.173	+0.966
2	do	493	Wm. Bond & Son		+1.441	+0.891	+0.176	+0.412	+0.423	+0.287
3	Bliss	2843	John Bliss & Co		+0.549	+0.499	−0.146	+0.062	−0.184	−0.284
4	do	218	Wm. Bond & Son		+0.156	−1.037	−1.753	−1.138	−0.577	−1.141
5	Negus	292	do		−0.059	−0.894	−1.503	−1.138	−0.791	−1.177
6	do	1596 M. T. B. C.	T. S. & J. D. Negus		+2.441	+1.249	+0.390	+1.212	+1.709	+1.251
7	do	1739	do		+3.013	+1.249	+0.069	+0.212	+0.601	+0.251
8	do	1189	do		+2.870	+0.927	+0.211	+0.862	+1.494	+1.359
9	do	1459	do		−1.094	−2.180	−2.396	−1.338	−0.506	−1.070
10	do	514	Wm. Bond & Son		+1.656	+0.749	−0.181	+0.212	+0.316	+0.216
11	do	1291	T. S. & J. D. Negus		+0.334	−0.894	−1.503	−0.188	+0.709	+0.073
12	do	1113	do		+1.441	+0.534	+0.319	+0.862	+0.959	+0.323
13	do	1749	do		+2.334	+0.999	−0.003	+0.762	+1.209	+0.859
14	do	1773	do		+0.763	+0.356	+0.033	+0.012	+0.530	+0.394
15	do	1074	do		+2.941	+1.141	+0.390	+1.862	+2.280	+1.323
16	do	1300	do		+3.441	+2.249	+0.997	+1.612	+1.959	+1.251
17	Bliss	2394	M. F. Dent		+0.227	+1.391	+1.104	−0.088	−0.756	−0.641
18	do	2831	Chas. Frodsham		+0.299	−0.644	−1.003	+0.162	+0.851	+0.251
19	Negus	1265	T. S. & J. D. Negus		+1.513	+0.391	+0.104	+1.112	+1.959	+1.501
20	do	1059	do		+1.156	+0.213	+0.569	+1.712	+2.423	+2.251
21	do	1464	do		+2.656	+1.356	+0.390	+1.162	+2.280	+2.037
22	do	772	do		+2.013	+1.177	+2.033	+2.862	+2.887	+2.466

Relative number.	Repaired by—	Chronometer number.	Maker.	Time	Feb. 6 to Feb. 13.	Feb. 15 to Feb. 20.	Feb. 21 to Feb. 28.	Mar. 1 to Mar. 8.	Mar. 8 to Mar. 15.	Mar. 15 to Mar. 22.
				Temperature, Fahrenheit	70.06°	54.75°	45.48°	61.24°	63.68°	65.87°
				Relative humidity, per cent	67.0	68.6	69.5	57.0	57.6	62.6
1	Negus	1783	T. S. & J. D. Negus		+1.231	+1.532	+1.654	+1.426	+1.266	+1.191
2	do	493	Wm. Bond & Son		−0.019	+0.482	+1.369	+0.640	+0.444	+0.441
3	Bliss	2843	John Bliss & Co		−0.054	+0.382	+0.226	+0.497	+0.694	+0.834
4	do	218	Wm. Bond & Son		−1.840	−0.918	+0.047	−0.896	−1.163	−1.094
5	Negus	292	do		−1.590	−0.768	+0.297	−0.324	−0.770	−0.880
6	do	1596 M. T. B. C.	T. S. & J. D. Negus		+0.874	+1.632	+2.869	+1.319	+1.016	+1.049
7	do	1739	do		+0.089	+1.482	+3.226	+1.069	+0.623	+0.549
8	do	1189	do		+0.803	+1.582	+2.547	+1.319	+1.051	+1.084
9	do	1459	do		−1.697	−1.268	−0.489	−1.574	−1.806	−1.737
10	do	514	Wm. Bond & Son		−0.269	+0.782	+1.940	+0.569	+0.051	−0.059
11	do	1291	T. S. & J. D. Negus		−0.983	−0.518	+0.297	−0.824	−1.091	−1.023
12	do	1113	do		−0.411	+0.882	+1.726	+0.497	+0.087	+0.191
13	do	1749	do		+0.803	+1.682	+3.011	+0.926	+0.623	+0.549
14	do	1773	do		+0.589	+1.432	+1.226	+0.926	+0.551	+0.549
15	do	1074	do		+0.696	+1.282	+2.547	+1.354	+1.266	+1.120
16	do	1300	do		+0.803	+1.932	+3.119	+0.997	+0.551	+0.584
17	Bliss	2394	M. F. Dent		+0.446	+0.982	+0.726	+1.211	+1.194	+0.977
18	do	2831	Chas. Frodsham		−1.161	−0.468	+0.583	−0.646	−1.306	−1.130
19	Negus	1265	T. S. & J. D. Negus		+0.803	+1.432	+2.726	+0.854	+0.587	+0.620
20	do	1059	do		+0.731	+1.132	+2.154	+0.140	−0.234	+0.049
21	do	1464	do		+1.589	+2.282	+3.119	+1.783	+1.551	+1.549
22	do	772	do		+2.374	+3.482	+4.654	+4.104	+2.944	+3.084

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Record of trial of repaired chronometers (*December, 1895, to May, 1896*)—Continued.

[In temperature room from December 14, 1895, to February 28, 1896; after that in chronometer room.]

Relative number.	Repaired by—	Chronometer number.	Maker.	Mar. 22 to Mar. 29.	Mar. 29 to Apr. 5.	Apr. 5 to Apr. 12.	Apr. 12 to Apr. 19.	Apr. 19 to Apr. 26.	Apr. 26 to May 3.	May 3 to May 10.
	Time									
	Temperature, Fahrenheit			66.27°	70.42°	67.09°	72.70°	73.91°	67.97°	68.86°
	Relative humidity, per cent			56.7	60.8	60.9	62.0	61.4	63.6	66.0
1	Negus	1783	T. S. & J. D. Negus	+1.133	+1.021	+1.246	+0.960	+1.044	+1.296	+1.169
2	...do..	493	Wm. Bond & Son.	+0.347	+0.129	+0.031	+0.031	+0.116	—0.026	—0.153
3	Bliss..	2843	John Bliss & Co..	+0.347	+0.343	+0.674	+0.353	+0.044	—0.133	—0.081
4	...do..	218	Wm. Bond & Son.	—1.367	—1.407	—1.540	—1.540	—1.456	—1.490	—1.581
5	Negus	292	.....do	—1.117	—1.764	—1.326	—1.754	—1.634	—1.561	—1.903
6	...do..	1596 (M. T. B. C.)	T. S. & J. D. Negus	+0.919	+0.771	+0.924	+0.817	+0.866	+0.796	+0.776
7	...do..	1739	.....do	+0.490	+0.093	+0.389	—0.040	+0.044	+0.153	—0.046
8	...do..	1189	.....do	+1.169	+0.843	+0.960	+0.781	+0.973	+0.653	+0.883
9	...do..	1459	.....do	—1.766	—1.907	—1.790	—1.969	—1.813	—1.811	—1.796
10	...do..	514	Wm. Bond & Son.	—0.153	—0.693	—0.504	—1.040	—1.027	—1.061	—1.224
11	...do..	1291	T. S. & J. D. Negus	—0.831	—0.979	—0.969	—1.040	—0.884	—1.204	—1.189
12	...do..	1113	.....do	+0.240	+0.057	+0.174	—0.219	—0.027	—0.276	—0.439
13	...do..	1749	.....do	+0.347	+0.414	+0.496	+0.210	+0.116	+0.189	+0.311
14	...do..	1773	.....do	+0.490	+0.093	+0.281	—0.004	+0.044	+0.153	—0.046
15	...do..	1074	.....do	+1.061	+1.057	+0.924	+1.067	+1.509	+0.939	+0.740
16	...do..	1300	.....do	+0.490	+0.450	+0.710	+0.210	+0.437	+0.546	+0.526
17	Bliss..	2394	M. F. Dent	+1.026	+1.379	+1.210	+0.817	+0.687	+0.796	+0.669
18	...do..	2831	Chas. Frodsham..	—1.224	—1.764	—1.611	—1.754	—1.491	—1.704	—1.474
19	Negus	1265	T. S. & J. D. Negus	+0.597	+0.521	+0.531	+0.567	+0.580	+0.510	+0.454
20	...do..	1059	.....do	—0.010	—0.086	—0.147	+0.103	+0.259	+0.260	+0.204
21	...do..	1464	.....do	+1.454	+1.307	+1.389	+1.317	+1.616	+1.689	+1.526
22	...do..	772	.....do	+2.740	+2.379	+2.210	+2.174	+1.616	+1.439	+1.490

Relative number.	Repaired by—	Chronometer number.	Maker.	May 10 to May 17.	May 17 to May 24.	Temperature of compensation.	Temperature, constant.	First trial number.	Final trial number.
	Time								
	Temperature, Fahrenheit			74.91°	74.17°				
	Relative humidity, per cent			65.1	66.3				
						°			
1	Negus..	1783	T. S. & J. D. Negus..	+0.754	+0.886	47.576	—0.00026	5.7995	7.2636
2	...do....	493	Wm. Bond & Son....	—0.174	—0.007	72.839	+0.00193	7.5758	8.4500
3	Bliss....	2843	John Bliss & Co.....	—0.103	+0.029	77.847	116	9.9247	13.4067
4	...do....	218	Wm. Bond & Son....	—1.603	—1.579	70.760	324	12.4234	13.4395
5	Negus..	292	.....do	—1.996	—1.864	72.177	242	8.1488	14.6055
6	...do....	1596 (M. T. B. C.)	T. S. & J. D. Negus..	+0.790	+0.850	71.060	309	14.2587	14.6468
7	...do....	1739	.....do	—0.246	—0.186	75.917	314	17.1545	18.4000
8	...do....	1189	.....do	+0.719	+0.743	70.744	297	17.5937	18.8169
9	...do....	1459	.....do	—1.853	—1.757	66.584	257	19.3619	20.5218
10	...do....	514	Wm. Bond & Son....	—1.460	—1.436	72.859	313	14.4158	20.5811
11	...do....	1291	T. S. & J. D. Negus..	—1.067	—1.079	67.107	379	19.8702	20.5995
12	...do....	1113	.....do	—0.317	—0.650	70.563	306	17.9463	20.7052
13	...do....	1749	.....do	+0.076	+0.207	72.905	206	20.4562	21.1906
14	...do....	1773	.....do	—0.317	—0.079	81.012	103	19.7575	21.8774
15	...do....	1074	.....do	+0.754	+0.850	68.270	378	19.3273	22.2309
16	...do....	1300	.....do	+0.254	+0.279	72.832	378	21.7328	23.0052
17	Bliss....	2394	M. F. Dent.....	+0.647	+0.600	54.058	—0.00162	20.8816	24.4198
18	...do....	2831	Chas. Frodsham.....	—1.639	—1.436	66.776	+0.00399	19.1207	24.4799
19	Negus..	1265	T. S. & J. D. Negus..	+0.504	+0.493	67.671	288	25.4090	25.9958
20	...do....	1059	.....do	+0.361	+0.779	62.693	299	25.4617	27.9866
21	...do....	1464	.....do	+1.433	+1.421	71.089	316	34.1516	34.9907
22	...do....	772	.....do	+1.397	+1.421	65.654	129	62.7465	88.4717

NOTE.—The sign + signifies a loosing rate. The sign — signifies a gaining rate.

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Record of competitive trial of chronometers (December, 1895, to May, 1896).

[In temperature room from December 14, 1895, to February 28, 1896; after that in chronometer room.]

Relative number.	Chronometer number.	Maker.	Dec. 14 to Dec. 21.	Dec. 22 to Dec. 29.	Jan. 4 to Jan. 11.	Jan. 13 to Jan. 18.	Jan. 20 to Jan. 27.	Jan. 28 to Feb. 4.
	Time							
	Temperature, Fahrenheit		46.22°	54.95°	70.00°	85.11°	89.99°	84.94°
	Relative humidity, per cent		68.6	68.1	69.6	68.8	69.5	68.8
1	1780	T. S. & J. D. Negus *b*	+0.656	+0.356	+0.390	+0.412	+0.709	+0.537
2	1850	do *a*	+2.406	+1.177	+0.819	+1.712	+2.137	+1.466
3	1835	do *a*	−0.094	−1.359	−1.824	−0.888	−0.149	−0.820
4	1843	do *a*	+1.406	+0.391	−0.074	+0.512	+1.066	+0.430
5	1737	do *a*	−0.416	−1.359	−1.003	−0.088	+0.423	−0.213
6	1834	do *a*	+1.406	+0.570	+0.604	+1.612	+2.173	+1.716
7	1802	do *a*	+0.977	−0.073	−0.824	+0.062	+0.351	−0.284
8	1813	do *a*	+2.441	+1.820	+1.569	+2.762	+3.994	+3.394
9	1809	do *b*	−1.416	−2.180	−1.431	−1.988	−1.791	−1.856
10	1832	do *a*	+1.906	+0.391	−0.869	−0.438	+0.066	−0.356
11	1839	do *b*	+0.513	−0.144	+0.140	+0.062	+0.494	−0.034
12	1789	do *b*	+0.441	+0.606	−0.110	+0.012	+0.316	+0.073
13	1849	do *a*	+2.691	+1.356	+0.569	+0.912	+0.994	+0.109
14	1890	do *a*	+2.763	+1.606	+1.104	+2.112	+3.101	+2.609
15	1025	H. H. Heinrich *c*	+0.691	−1.287	−1.753	−0.538	+0.209	−0.284
16	1833	T. S. & J. D. Negus *a*	+1.084	−0.430	−1.431	+0.412	+0.923	+0.430
17	994	H. H. Heinrich *a*	+0.084	−0.894	−2.074	−1.788	−1.363	−2.249
18	1022	do *a*	+0.263	−0.037	+0.319	+3.412	+4.351	+3.930
19	990	do *a*	+0.799	+1.070	−0.003	−0.188	+0.423	−0.409
20	1023	do *a*	+1.906	+0.606	−0.789	−0.388	−0.327	−0.856
21	1021	do *a*	+0.191	−0.251	−1.824	−1.338	−1.720	−2.820

Relative number.	Chronometer number.	Maker.	Feb. 6 to Feb. 13.	Feb. 15 to Feb. 20.	Feb. 21 to Feb. 28.	Mar. 1 to Mar. 8.	Mar. 8 to Mar. 15.	Mar. 15 to Mar. 22.
	Time							
	Temperature, Fahrenheit		70.06°	54.75°	45.48°	61.24°	63.68°	65.87°
	Relative humidity, per cent		67.0	68.6	69.5	57.0	57.5	62.6
1	1780	T. S. & J. D. Negus *b*	+0.231	+0.882	+0.797	+0.247	−0.020	−0.059
2	1850	do *a*	+0.696	+1.382	+2.440	+1.069	+0.766	+0.727
3	1835	do *a*	−1.661	−0.968	+0.011	−1.503	−1.806	−1.844
4	1843	do *a*	−0.376	+0.482	+1.404	+0.140	−0.377	−0.487
5	1737	do *a*	−1.019	−0.368	+0.119	−0.967	−1.163	−1.094
6	1834	do *a*	+0.803	+0.882	+1.190	−0.396	−0.663	−0.559
7	1802	do *a*	−1.090	−0.068	+1.476	−0.074	−0.306	−0.130
8	1813	do *a*	+2.017	+1.882	+2.190	+1.533	+1.230	+1.370
9	1809	do *b*	−1.447	−1.418	−1.381	−1.717	−1.663	−1.737
10	1832	do *a*	−0.626	+0.582	+2.119	−0.110	−0.806	−0.880
11	1839	do *b*	−0.054	−0.518	−1.167	−1.110	−1.234	−1.523
12	1789	do *b*	+0.089	+0.882	+0.297	+0.426	+0.123	+0.084
13	1849	do *a*	−0.269	+0.832	+2.261	+0.426	+0.230	+0.120
14	1890	do *a*	+1.946	+2.582	+3.297	+1.533	+1.051	+1.084
15	1025	H. H. Heinrich *c*	−1.054	−0.468	+0.547	+0.247	+0.266	+0.227
16	1833	T. S. & J. D. Negus *a*	−0.269	+0.482	+1.261	−0.146	−0.520	−0.559
17	994	H. H. Heinrich *a*	−3.090	−2.568	−1.524	−2.860	−2.949	−3.094
18	1022	do *a*	+2.196	+0.682	+0.226	+1.569	+1.694	+2.120
19	990	do *a*	−1.054	−0.268	−0.703	−0.253	−0.663	−0.559
20	1023	do *a*	−2.161	−0.118	+0.297	−1.146	−1.591	−1.559
21	1021	do *a*	−3.733	−3.418	−2.096	−2.646	−2.877	−2.594

a Ordinary compensation balance.
b Ordinary compensation balance with Negus correction.
c Heinrich's patent auxiliary balance.

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Record of competitive trial of chronometers (December, 1895, to May, 1896)—Continued.

[In temperature room from December 14, 1895, to February 28, 1896; after that in chronometer room.]

Relative number.	Chronometer number.	Maker.	Mar. 22 to Mar. 29.	Mar. 29 to Apr. 5.	Apr. 5 to Apr. 12.	Apr. 12 to Apr. 19.	Apr. 19 to Apr. 26.	Apr. 26 to May 3.
	Time							
	Temperature, Fahrenheit		66.27°	70.42°	67.09°	72.70°	73.91°	67.97°
	Relative humidity, per cent		56.7	60.8	60.9	62.0	61.4	63.6
1	1780	T. S. & J. D. Negus *b*	—0.117	+0.129	+0.067	+0.103	+0.473	+0.439
2	1850	do *a*	+0.597	+0.414	+0.567	+0.317	+0.259	+0.224
3	1835	do *a*	—1.867	—2.050	—2.004	—2.254	—2.027	—2.061
4	1843	do *a*	—0.474	—0.871	—0.861	—1.147	—0.991	—1.133
5	1737	do *a*	—1.224	—1.336	—1.326	—1.183	—1.170	—1.347
6	1834	do *a*	—0.689	—0.729	—0.647	—0.683	—0.384	—1.061
7	1802	do *a*	—0.331	—0.479	—0.397	—0.540	—0.599	—0.669
8	1813	do *a*	+1.347	+1.343	+1.246	+1.281	+1.616	+1.153
9	1809	do *b*	—1.867	—1.943	—1.826	—2.076	—2.099	—1.847
10	1832	do *a*	—1.010	—1.300	—1.004	—1.469	—1.313	—1.133
11	1839	do *b*	—1.867	—2.229	—2.290	—2.469	—2.384	—2.633
12	1789	do *b*	—0.046	—0.443	—0.219	—0.683	—0.634	—0.419
13	1849	do *a*	+0.061	—0.193	—0.004	—0.397	—0.813	—0.419
14	1890	do *a*	+0.990	+1.021	+0.996	+0.889	+1.009	+0.760
15	1025	H. H. Heinrich *c*	+0.061	—0.193	—0.219	—0.611	—0.599	—0.919
16	1833	T. S. & J. D. Negus *a*	—0.760	—0.836	—0.683	—0.826	—0.741	—0.847
17	994	H. H. Heinrich *a*	—3.153	—3.300	—3.076	—3.254	—3.313	—3.419
18	1022	do *a*	+2.133	+2.343	+1.996	+2.460	+2.544	+2.046
19	990	do *a*	—0.689	—1.157	—0.861	—1.219	—1.241	—1.169
20	1023	do *a*	—1.474	—1.800	—1.719	—1.969	—1.813	—1.919
21	1021	do *a*	—2.796	—2.657	—3.290	—2.611	—2.670	—3.204

Relative number.	Chronometer number.	Maker.	May 3 to May 10.	May 10 to May 17.	May 17 to May 24.	Temperature of compensation.	Temperature, constant.	First trial number.	Final trial number.
	Time								
	Temperature, Fahrenheit		68.86°	74.91°	74.17°				
	Relative humidity, per cent		66.0	65.1	66.3				
						°			
1	1780	T. S. & J. D. Negus *b*	+0.097	+0.076	+0.350	72.246	0.00103	5.4036	7.2478
2	1850	do *a*	+0.169	—0.067	—0.007	68.219	297	10.4931	13.9527
3	1835	do *a*	—2.296	—2.389	—2.293	68.349	323	12.3888	14.5115
4	1843	do *a*	—1.224	—1.281	—1.257	69.751	298	10.2662	14.7014
5	1737	do *a*	—1.367	—1.317	—1.364	64.624	222	14.4119	15.2843
6	1834	do *a*	—1.474	—1.496	—1.436	62.774	217	9.8915	15.4046
7	1802	do *a*	—0.796	—0.781	—0.721	70.114	380	17.3456	18.7856
8	1813	do *a*	+1.240	+1.433	+1.421	63.084	297	18.6428	19.8616
9	1809	do *b*	—1.939	—2.281	—2.114	68.840	—0.00185	18.7850	20.1098
10	1832	do *a*	—1.331	—1.674	—1.543	74.186	345	17.1242	21.0684
11	1839	do *b*	—2.760	—2.817	—2.757	76.432	—0.00088	13.5719	21.1344
12	1789	do *b*	—0.617	—0.924	—0.757	76.511	177	21.7738	24.3627
13	1849	do *a*	—0.581	—0.603	—0.579	73.320	286	24.1372	25.6086
14	1890	do *a*	+0.633	+0.683	+0.707	68.508	309	24.1176	26.6648
15	1025	H. H. Heinrich *c*	—0.724	—0.710	—0.543	67.625	384	23.1226	27.4907
16	1833	T. S. & J. D. Negus *a*	—0.831	—0.996	—0.936	68.553	472	40.3285	42.5815
17	994	H. H. Heinrich *a*	—3.760	—3.817	—3.650	71.479	310	48.5442	50.4074
18	1022	do *a*	+2.347	+2.754	+2.814	53.077	329	57.1485	58.4664
19	990	do *a*	—1.331	—1.567	—1.650	75.001	244	58.1964	60.7660
20	1023	do *a*	—2.010	—2.496	—2.686	72.485	563	83.5818	87.1956
21	1021	do *a*	—3.117	—2.639	—2.829	71.061	361	145.3915	150.1352

NOTE.—The sign + signifies a losing rate; the sign — signifies a gaining rate.

During the year 41 silver-case comparing watches have been subjected to trial, of which 20 were purchased; 12 silver-case stop watches were subjected to trial, all of which were rejected for failure to comply with requirements of specifications, and 12 more are now undergoing trial; 6 gold-case stop watches were subjected to trial with a view to the purchase of two for use of the Board of Trial of new vessels, but all failed to come up to the requirements of the specifications, and none were purchased.

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The 5½-inch meridian transit instrument is used in this department for the determination of time. It is in good condition and has been in continuous service since May, 1893, when it was installed in its present location. Observations are taken with this instrument every second or third night, when practicable, for the determination of the corrections and rates of the three clocks under control of the department, and daily comparisons of the clocks are made to check the correction of the standard mean-time clock.

The performance of the standard mean-time clock has been satisfactory, but having accelerated until its rate was inconveniently large (1.8 seconds), it was stopped on May 25 last and the pendulum lengthened, since which time its rate has been small, the variations in its rate following closely the barometric variations. During the interval from the stopping of the standard clock until its correction and rate could be determined by observation (a period of six days) the Seth Thomas mean-time clock was used as standard in the transmission of the noon signals. The performance of the Seth Thomas mean-time clock has not been satisfactory. It was taken down and examined by Mr. Gardner on July 11 last, and found to have some of its parts badly rusted. After being cleaned it was put up and started again on August 5, but the variations in its rate since that time have been greater than could reasonably be attributed to atmospheric conditions. This clock and the standard mean-time clock are mounted in the chronometer room and surrounded by wooden cases whereby the variations in temperature are not great.

The observing clock (sidereal) is mounted in the south transit room and, although surrounded by two wooden cases, is subjected to great variations in temperature; but, considering the conditions to which it has been subjected, its performance has been satisfactory. A record of the temperature in all three of the clock cases has been kept since August 27 last. The maximum and minimum thermometers that are kept in the cases have been read every morning, and also at the time of observations, so that it has been possible to determine the thermal and barometric coefficients of the clocks. The results, while not all that could be desired, nevertheless furnish means for a comparative study of the performance of the different clocks. The results are as follows: where y represents the barometric coefficient and z the thermal coefficient:

Standard mean-time clock:

$$y = +0.586\,s \pm .073.$$
$$z = +0.011\,s \pm .002.$$

Seth Thomas mean-time clock:

$$y = +0.281\,s \pm .099.$$
$$z = -0.018\,s \pm .003.$$

South transit observing clock:

$$y = +0.389\,s \pm .118.$$
$$z = +0.009\,s \pm .001.$$

The signs of the quantities show the effects of a rise in barometer or thermometer and are reversed for a fall. The barometric coefficient shows the change in daily rate for a change of 1 inch in the reading of the barometer while the thermal coefficient shows the change in the daily rate due to a change of 1° F. in the temperature.

The operation of the time service has been satisfactory so far as the transmission of signals from the Observatory is concerned. The mean-time of noon (75th meridian) as determined by observation has been sent out daily except Sundays. The average error for the year of noon

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signals sent out was 0.23 sec., and the maximum, resulting from a long spell of bad weather unfavorable for observing, was 1.42 secs. By the method adopted last February of having monthly reports from the branch hydrographic offices, the Observatory is enabled to find out whether the noon signal is transmitted regularly, and these reports show that it has been received at the various offices with a fair degree of regularity.

Computer F. E. Dennett, as assistant in the department, has rendered valuable and efficient service.

Very respectfully,

W. V. BRONAUGH,
Lieutenant United States Navy, Head of Department.

DEPARTMENT OF MAGNETISM AND METEOROLOGY.

Lieutenant David Peacock, United States Navy, was the head of this department during the year. His report gives the following details:

The self-recording instruments at present consist of the horizontal force, declination, two vertical force and a temperature-recording instrument. The Kew vertical force instrument has been thoroughly overhauled twice during the year and is now giving excellent results. The temperature-recording instrument gives a very accurate record of the temperature, and the advantage of having a continuous temperature record is very great, especially in reducing the records of the vertical force instruments.

Observations have been taken from time to time in order to determine the effect of a change of temperature on the reading of the magnetograms, and these coefficients have been carefully determined.

The deflection experiments for determining the value of a scale division of the horizontal and vertical force instruments have been made as often as possible. As these experiments have to be made during the night, from 10 p. m. until 5 a. m., on account of the electric railway, it has not been practicable to make as many experiments as desirable; at the same time they have been made whenever there was reason to believe that the value of the scale division had changed.

The temperature of the vault has been kept almost constant during the year, the only variations being during the summer months.

The instruments for eye or absolute observations consist of the declinometer, horizontal force or magnetic theodolite, and the dip circle. With the declinometer at least two observations were taken each day, the mean of the results of these observations giving the base-line value for the self-recording declinometer.

With the magnetic theodolite, vibration and deflection experiments were made about every fourth day during the year. These were for determining the horizontal intensity, and from them the base-line value for the horizontal force records was determined.

With the dip circle observations were taken about every fourth day for the dip or inclination. From these observations the base-line value for the vertical force records was determined.

At times observations were taken for determining the true meridian which is used in connection with the declinometer.

The following observations and experiments have been made during the year:

For declination	756
Deflection experiments for horizontal intensity	90
Vibration experiments for horizontal intensity	90
For dip or inclination	88

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The results of all the absolute observations have been reduced, and the continuous records of the horizontal force, declination, two vertical force, and temperature-recording instruments have been tabulated for each hour of the year.

During the year the old horizontal force instrument and dip circle were moved to spare piers, and the piers that they occupied prepared for the new instruments, upon which the latter are now mounted.

The proof sheets for the publication of the records of 1894 have been read and arranged for the Public Printer.

The records for 1895 have been reduced, tabulated, and arranged, and are ready for the printer. The entire work of computing, writing, copying, and making the drawings was done by Lieutenant Peacock.

During the year simultaneous observations of the declination and horizontal force instruments have been made several times. These observations were taken every five seconds for one hour. They were taken, principally, to determine the fields of simultaneous movements of a magnetic needle when acted upon only by the earth's magnetic force. In this work Assistant Astronomer George A. Hill and Computer Theo I. King assisted.

The new magnetic theodolite and dip circle made by Dr. M. Th. Edelmann have been installed. The essential parts are accurately and well made, but the details of finish and minor attachments were not satisfactory. Nevertheless, the efficiency and accuracy of the instruments are not impaired, as all necessary changes and substitutions have, after considerable trouble and delay, been made.

The following coefficients and constants have been determined for use with the new magnetic theodolite:

Temperature coefficients, designated as q and q', $q=0.00044, q'=0.00000079$.

The moment of inertia, the mean value of many observations, was 0.0260167.

The value of a scale division in the telescope of the magnetic theodolite = 59.2114″.

The coefficient of induction designated as $\mu = 0.00000575$.

In making the reductions the following values were taken. Ratio of circumference to diameter of circle = 3.141592. The linear coefficient of expansion of brass = 0.0000185. The linear coefficient of expansion of steel = 0.0000120. The error of graduation of the deflecting bar is zero.

The inertia bar was weighed and measured at the Government department of weights and measures at the United States Coast and Geodetic Survey Office, the dimensions being as follows:

Inertia bar No. 2:
Mass, 135.2928 grammes.
Mean length, 99.884 mm. at temperature 13.35° C.
Mean diameter 14.189 mm. at temperature 13.35° C.

In determining the above coefficients many independent observations were taken and in most cases entirely different methods were used, the results obtained by the several methods agreeing very closely.

As the magnets are new it is important that in a few years these coefficients and constants be checked by new observations and experiments, as the conditions of new magnets are liable to change.

The new instruments will be used for the observations after June 30, 1896. In the installation of these instruments—as such work had never been done at this Observatory before—much apparatus had to be designed and improvised. In this work Mr. Gardner rendered very valuable assistance. Mr. F. E. Dennett, computer, is entitled to credit

for assisting in adjusting the instruments and in reducing the formulæ for use in computing and reducing the observations.

The following tables have been computed and arranged for use in the reductions of the observations and experiments made with the new magnetic theodolite:

Table I, for the value of P, the argument being log sin u — log sin u'.

Table II, temperature corrections to be applied to the value of P as found in Table I. Arguments are log sin u — log sin u', and the mean temperature of the deflection experiment.

Table III, giving the logarithm of the square of the time of vibration, argument being the time for 180 vibrations.

Table IV, giving the value of $\frac{H}{F}$ = ratio of the force of torsion of the suspending thread of the vibration magnet to the magnetic directive force, argument being the scale division for 90° torsion.

Table V, giving the value of $[b]=(q+3\varepsilon)\ t_d$, the argument being the mean temperature of the deflection experiment.

Table VI, giving the logarithm of $(1+b)$, the argument being the mean temperature of the deflection experiment.

Table VII, giving the value of $a'=(q+2\varepsilon)\ t_v+q'\ t_v{}^2$, the argument being the mean temperature of the vibration experiment.

Table VIII, giving the corrections of the thermometer, No. 7562, used in making vibration and deflection experiments.

Table IX, giving the value of $\frac{2s}{86400}$ when s is the daily rate of the chronometer, the argument being the daily rate of chronometer.

Table X, giving the value of $\mu \div \left(\frac{m}{X}\right)_0$, the argument being the mean of the logarithms of B $(1+b)$ sin u and B $(1+b)$ sin u'.

Table XI, giving the co-logaritim of $\left[2\left(1-\frac{2\mu}{r_0{}^3}+\frac{P}{r_0{}^2}\right)\right]$, the argument being the value of P.

Table XII, giving the moment of inertia and the value of K_t, the moment of inertia of the vibration magnet, including its suspending frame and other appendages, at temperature 0° C.

Table XIII, giving the value of $r_0=0.3$ meter and $r_0=0.4$ meter at different temperatures and the logarithms of the cubes of these values.

The meteorological records have been taken and recorded by Messrs. Horigan, Cahill, and Henderson, watchmen.

Very respectfully,

DAVID PEACOCK,
Lieutenant, U. S. Navy, Head of Department.

BUILDINGS AND GROUNDS.

Provision has been made for the erection of two houses for observers. It is believed that these will be completed and ready for occupancy by January 1, 1897.

Congress at its last session appropriated $1,800 for repairs to the main building, the necessity of which was set forth in my last report. These repairs will be made with all practicable dispatch consistent with proper protection to the building while the work is being done.

The progress in grading and improving the grounds and roads has been satisfactory, and the results are beginning to be manifest in the appearance of the surroundings of the Observatory.

LIBRARY.

The duties of the librarian were performed by Assistant Librarian William D. Horigan, under the general supervision of the library committee.

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The contents of the library at the beginning and ending of the fiscal year 1895–96 were:

	Volumes.	Pamphlets.	Total.
Contents, July 1, 1895	14,906	3,286	18,192
Accessions	550	18	568
Contents, July 1, 1896	15,456	3,304	18,760

Of the 568 accessions 253 were received as exchanges and 315 were purchased.

The clerical work of the Observatory, which embraces the preparation of requisitions and vouchers and keeping the accounts of expenditures, has been efficiently performed by Mr. Thomas Harrison, assisted by Mr. Robert H. Coker.

The estimates for the fiscal year ending June 30, 1898, are herewith submitted.

Very respectfully,

R. L. PHYTHIAN,
Commodore, U. S. N., Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

The following is the report of the naval inspector of electric lighting:

The electric plants of the following ships have been completed and are now in operation, viz: *Indiana*, *Massachusetts*, *Oregon*, *Monadnock*, and *Terror*. The plant of the *Brooklyn* is also practically finished and that of the *Puritan* well advanced. The installation of the plants of the *Iowa*, *Nashville*, *Wilmington*, *Helena*, gunboats Nos. 14 and 15, and torpedo boats Nos. 3, 4, 5, 6, 7, and 8 has been carried on so as to keep pace with the work of construction. Light lists and wiring plans for the *Kearsarge* and *Kentucky* have been prepared.

As two of the turrets and several of the ammunition hoists of the *Brooklyn* are to be operated by means of electric motors, the generating plant of that ship will consist of three generators of 32 kilowatts each and two of 24 kilowatts, giving a total output of 144 kilowatts, which is nearly double that of the *New York's* plant. The switchboard connections will be so designed that each and all of the generators will be available for both lighting and motor service.

The plants of ships on active service have been kept in repair, and have, in general, operated satisfactorily. Those of the *Baltimore*, *Concord*, *Petrel*, and *Charleston* are receiving a thorough overhauling while the ships are temporarily out of commission. The new plant of the *Boston* was completed during the year, and those of the *Miantonomoh* and *Vesuvius* are being put in readiness for service.

Attention has been given to the improvement of the electrical apparatus and material used in ships' installations, guided by the experience gained in their practical operation in service. New devices which gave promise of being superior to those in use, or to be of value as additions to the electric plants of ships, have been tried, and, if found satisfactory, have been adopted.

The experiments referred to in my last report have been in progress at the Norfolk and New York navy-yards, but thus far only a moderate degree of success has been obtained. The attempts to blow a considerable number of fog horns or whistles simultaneously by means of compressed air, with the view of using such a system for signalling the

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order to close water-tight doors, have not been sufficiently satisfactory to warrant the adoption of the plan.

In the trials which have been made of using a tangential water wheel for driving a dynamo, the water pressure being supplied by means of steam pumps, difficulty has been encountered in governing the speed of the wheel within the limits necessary for the proper operation of the dynamo, and as yet, although several means have been tried, none have proved practicable.

With the ordinary form of incandescent lamp, the filament continues to glow for an appreciable time after the current is turned off, which feature is prejudicial to its use for signalling purposes. The attempt is being made to overcome this difficulty by making a lamp with a number of small filaments connected in multiple, which, while giving in the aggregate the desired candlepower, will quickly cease to glow on account of the small size of the several filaments. A lamp has been tested which gives excellent results in this respect, but which requires further improvement in some of its details.

A small incandescent lamp of 6 candlepower, and of the proper shape and size, has been designed for the inspection of the interior of automobile torpedoes, and will hereafter be supplied to ships for that purpose.

With the increasingly complicated structural arrangements of our new ships has arisen the necessity for rapid, convenient, and efficient means of interior communication between their several compartments. Telephones have been installed extensively in the larger new ships, and, it is believed, will give better service than voice pipes, excepting in cases where voice-pipe leads can be made straight and short.

Increased facilities for making repairs to the electric plants of ships have been provided at the New York, Norfolk, and Mare Island navy-yards, with the result of considerably decreasing the cost and time required for such work.

Respectfully submitted.

W. MAYNARD,
Commander, U. S. Navy.

The following is the report of the superintendent of compasses:

Compass reports, reports of magnetic surveys, and observations relating to compasses taken while the vessels were in dock have been received, examined, and placed on file; one invention pertaining to method of compensating compasses has been submitted, carefully examined, and reported upon; parts of new compasses and instruments have been examined in detail in the office and final examinations of completed instruments have been made by an officer from the office at the manufacturer's or at the Naval Observatory. Observations for location, adjustment, and compensation of compasses, and approximate or complete compensations, have been made by the officers of the office in the following vessels: *Indiana*, *Maine*, *Katahdin*, *Terror*, *Massachusetts*, *Brooklyn*, *Standish*, *Bancroft*, and *Texas* (the latter after extensive repairs). Approximate locations for compasses have been given from the plans submitted for vessels now under construction.

Notwithstanding the very unfavorable conditions surrounding the compasses of the *Indiana*, *Massachusetts*, *Texas*, and some other vessels, by which extraordinary magnetic forces, far exceeding in strength the horizontal or directive force of the earth, it has been found that the binnacle now in use fully meets all requirements in supplying the necessary neutralizing forces, and the compensations made prove satisfactory.

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REPORT

OF THE

SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1897.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1897.

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REPORT

OF THE

SUPERINTENDENT OF THE UNITED STATES NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 15, 1897.

SIR: I have the honor to submit herewith the report of the operations of the United States Naval Observatory for the fiscal year ending June 30, 1897.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

The Astronomical Director reports as follows:

THE 26-INCH EQUATORIAL TELESCOPE.

[Prof. STIMSON J. BROWN, U. S. N., in charge.]

As usual, this instrument has been employed almost exclusively on faint and difficult objects which could not well be reached by smaller telescopes. The work accomplished during the year ending June 30, 1897, was as follows:

Brook's periodic comet, 1889 V = 1896 VI, was observed twenty-three times.

Giacobini's comet, 1896 V, was observed five times.

Perrine's comet, 1896 f = 1897 I, was observed on November 6, 8, and 9. On the latter date it was visible in the 5-inch finder, and therefore the work of making further observations on it was transferred to the 12-inch equatorial.

Perrine's periodic comet, 1896 VII, was observed three times.

The observations of these four comets have all been completely reduced and published in the volumes of the Astronomical Journal.

During the months of May and June an attempt was made to find D'Arrest's comet, the ephemeris used having been carried forward from the last apparition, but the search proved unsuccessful, partly on account of unfavorable weather and partly because the motion of the comet kept it continually on the verge of the morning twilight.

The satellites of Mars were observed whenever possible from November 18 to December 28, 1896, and during that period 24 observations of Deimos and 6 observations of Phobos were made by the method of position angles and distances.

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On March 29, 1897, observations were begun on what is intended to be a general revision of the more important double stars, such as well-known binaries, suspected binaries, and new or difficult doubles. Although nearly every subsequent clear night, except Sundays, has been utilized for that purpose, only 98 observations have been secured, while an equal number of attempts proved futile. Out of thirty-nine nights of actual work fifteen proved fairly good, but on only three of them could so high a power as 888 be used. On the remaining twenty-four nights observations were either impossible or limited to objects which would have been easily within reach of a 12-inch telescope under favorable conditions of weather. As a part of this work, Sirius and Procyon were examined in the early twilight, but the condition of the sky was unfavorable, and nothing was seen of their companions.

Last January the Moon passed very near to Mars, and arrangements were made to secure photographs of the spectra of the two bodies under nearly identical conditions. Trial spectra were obtained on both objects, but a long period of cloudy weather rendered the bodies invisible at the time of the January conjunction, and when the February conjunction arrived Mars was so far from the Earth that the scheme was impracticable.

The diameters of Mercury and Venus have been measured with the filar micrometer whenever sufficiently favorable conditions occurred. The observations of Mercury have little value on account of the unsteadiness of the images, but on three occasions the images of Venus were very fine for daylight observations, and as the resulting diameter of the planet at distance unity they gave, respectively, 17.60″, 17.65″, and 17.56″.

In addition to the usual routine office work the observations of Titan and Iapetus for 1894, 1895, and 1896 have been completely reduced, and the solution of the normal equations for the correction of the elements has been finished, but as the work has all been done by Professor Brown he thinks it should yet be checked by some one else, in order to guard against the possibility of systematic errors in the computed coordinates and in the coefficients of the observation equations. There were 150 equations of condition, equally distributed between the three years, and also between the two coordinates $\Delta\alpha$ and $\Delta\delta$. The probable error of a single observation is $\pm 0.313''$, and the resulting mass of Saturn is, from Titan 1:3490.3, and from Iapetus 1:3489.2.

The 26-inch telescope has remained in admirable order throughout the year, and no changes whatever have been made in it. On August 28, 1896, the contact piece for automatically stopping the elevating floor when it reaches its highest point was accidentally broken, and on September 9 it was replaced by a new casting. As originally arranged, the water pressure for raising and lowering the elevating floor was obtained from a pair of steam pumps situated in the basement of the main building of the Observatory. This was inconvenient, because 60 pounds of steam was required to work the pumps, and that pressure seldom existed in the boilers unless it was specially gotten up for the purpose. When the water from the new high-service reservoir was laid on to the city mains it was found that the pressure in them was about 74 pounds per square inch, and although that was 16 pounds less than the pressure usually given by the steam pumps, the Superintendent of the Observatory suggested that it might suffice to work both the elevating floor of the 26-inch telescope and the elevator in the main building. This suggestion having been confirmed by a rough calculation,

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on December 7, 1896, the city water pipes were connected with the elevating apparatus in question, and although the floors rose rather more slowly than under the action of the steam pumps, they have been worked in that way ever since because the diminution of speed is more than compensated for by the circumstance that the water pressure is always available.

Ever since the removal from the old Naval Observatory, the chronograph belonging to the meridian instrument Stackpole & Brother, No. 1502, has been used in connection with the 26-inch equatorial, because the chronograph properly belonging to the latter instrument required a space of 106 inches for the fall of its weight, and that could not conveniently be obtained in the new buildings. During the present summer the last-mentioned chronograph was put into the hands of Messrs. Warren & Swasey, with instructions to reduce the fall of its weight to 36 inches. That having been done, the instrument was returned to the Observatory on June 14, 1897, and will be brought into use as soon as possible.

THE 12-INCH EQUATORIAL TELESCOPE.

[Prof. EDGAR FRISBY, U. S. N., in charge.]

The work done with this telescope during the year ending June 30, 1897, was as follows:

Thirty-three observations of asteroids were made, namely, 3 of Flora (8), 2 of Psyche (16), 3 of Nemausa (51), 1 of Sappho (80), 2 of Sylvia (87), 2 of Amalthea (113), 3 of Electra (130), 3 of Ismene (190), 6 of Nephthys (287), 1 of (346), 5 of (386), and 2 of (387).

Perrine's comet, 1896 f=1897 I, was observed six times.

Perrine's periodic comet, 1896 g=1896 VII, was observed six times.

The positions of two stars were measured for use in connection with the work of the 26-inch telescope.

Eight occultations of stars by the moon and 5 eclipses of Jupiter's satellites were observed.

The diameter of Venus was measured on seven different days, and the Sun was examined for spots on four days.

Nearly all of the above-mentioned observations are reduced up to date, and those requiring prompt publication have been printed in the Astronomical Journal. In addition to this, Professor Frisby has found time to compute an ephemeris of the rising and setting of the moon at Washington for the year 1897, and also to do a great deal of work on the reduction of the photographs of the transit of Mercury of November 10, 1894.

On Tuesday and Thursday evenings of each week, weather permitting, the 12-inch telescope has been used for the exhibition of celestial objects to visitors. During the year 3,260 permits were issued to such visitors by the Observatory, and a large additional number were issued by the Bureau of Equipment.

During the last twelve months certain additions and repairs were made to this telescope by Mr. M. E. Kahler, as follows:

September 3, 1896, a new leather cap was provided for the finder. September 8 a clamp was provided for the draw tube of the finder, and, as the diaphragms in the sliding tube of the main telescope cut off the outer edge of the field when low-powered Huygenian eyepieces were employed, they were removed and replaced by larger ones. The object glasses furnished with the long microscopes for reading the right

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ascension and declination fine circles gave very bad definition on account of excessive spherical aberration, and to remedy that defect they were replaced by new objectives ground to curves specially computed by the Astronomical Director, the change being made in the declination microscopes on December 1, and in the right ascension microscopes on December 26. About the middle of February, 1897, the machinery of the dials for indicating the position of the telescope got slightly out of order, and on February 18 it was taken down, cleaned, oiled, and repaired.

THE 9.14-INCH TRANSIT CIRCLE.

[Assistant Astronomer AARON N. SKINNER, in charge.]

In the work with this instrument Assistant Astronomer Skinner has been aided during the year, for the periods specified, by the following-named gentlemen:

Assistant Astronomer H. M. Paul to February 15, 1897, when he was transferred to the time service; Mr. Theo I. King throughout the year, in the grade of computer until April 20, 1897, and subsequently in the grade of assistant astronomer; Computer Frank B. Littell until September 21, 1896, when he resigned, and after June 19, 1897, when he was reinstated; Computer E. A. Boeger throughout the year; Computer G. K. Lawton from the date of his appointment, October 20, 1896. Since March 23, 1897, Computer William M. Brown has aided in the observing, but not in the computing.

As the observations for the German Astronomical Society's zone, lying between 13° 50′ and 18° 10′ of south declination, were substantially completed last year, while the reductions are still far in arrears, it was thought best to limit the work of the transit circle during the present year to observations of the Sun, Moon, and planets, together with such stars as were wanted for special purposes, and the minimum number of Ephemeris stars necessary for determining instrumental constants.

The observations actually made during the twelve months ending June 30, 1897, were as follows:

Stars required for completing the zone −13° 50′ to −18° 10′, 435; zero stars for zones, 148; American Ephemeris stars, 2,832; miscellaneous stars, 109; wire interval stars, 73; Sun, 177; Moon, 122; Mercury, 87; Venus, 140; Mars, 44; Jupiter, 45; Saturn, 59; Uranus, 58; Neptune, 39; Flora (8), 6; Psyche (16), 6; Nemausa (51), 13; Sappho (80), 4; (346), 7. Total, 4,404.

In compliance with special requests, the positions of certain stars were observed and furnished to the parties named, as follows:

From the zone −13° 50′ to −18° 10′, 88 star places to Dr. J. G. Hagen, S. J., of Georgetown College Observatory, Washington, D. C., and 12 star places to Mr. A. Stichtenoth, of Göttingen, Germany; each of these places depending on two or more observations. To Prof. J. R. Eastman, U. S. N., 4 star places were furnished; to Prof. Edgar Frisby, U. S. N., 2 star places were furnished, each depending upon three observations; and to Prof. S. J. Brown, U. S. N., 9 star places were furnished, each depending upon three to five observations. For Prof. C. L. Doolittle, of the Flower Observatory, Philadelphia, Pa., observations have been made upon 6 stars, but they are not yet reduced.

The state of the reductions of the zone observations is as follows: In right ascension, the interpolation of the clock corrections has been fin-

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ished, but no progress has been made in the interpolation in the reductions from the date of observation to 1900. In declination, the interpolation of the refractions has been finished, but no progress has been made in the interpolation of the reductions from the date of observation to 1900. The work necessary for completing the reductions is as follows: The preparation of the reduction tables for zones 165–182, inclusive; the interpolation of the reductions in right ascension and declination from the date of observation to 1900; the assembling of the observations in the order of right ascensions and the taking of the means; the computation of the annual precessions and secular variations, both in right ascension and in declination.

The state of the reductions of the observations of the Sun, Moon, and planets is as follows: The chronograph sheets have been read to date; the means of the times of transit, microscope readings, and telescope micrometer readings have been taken to May 13, 1897; the observations have been partially entered on the reduction sheets, and a small amount of work has been done on these sheets. The work necessary for the completion of the reductions is as follows: The completion of the means of the times of transit, microscope readings, and telescope micrometer readings; the completion of the entries on the reduction sheets; the reduction on the sheets of all the Sun, Moon, and planet work from October 10, 1894, to date, only a small part of which has been done.

A comparison of this statement with the report of July 1, 1896, shows that the reductions have fallen further into arrears during the last fiscal year. This is due to two facts: First, the computing force attached to the transit circle at the beginning of the year was too small to do the work required of it, and, second, that force was diminished by one man from February 15, 1897, when Assistant Astronomer Paul was transferred to the time service, until June 19, 1897, when Computer Littell was reinstated.

Experience having shown that the meridian mark belonging to the transit circle was considerably inside the principal focus of the lens used for viewing it, an alteration in the position of the mark became necessary. The place which it should occupy having been very carefully determined, a hole was dug in the ground 6 feet square and 6 feet deep. This was filled with concrete, and upon the latter was built a brick pier 35½ inches square and 35½ inches high. The pier was capped with a marble slab 38 inches square and 4½ inches thick, upon which the meridian mark was mounted. The exact distance from the long focus lens to the new meridian mark was found to be 380.0 feet, which is 7.87 feet greater than the distance of the old mark. The new pier was built during the month of October, 1896, and the mark was transferred to it on October 28.

The illumination of the field of the transit circle being unsatisfactory when bright webs were required on a dark ground, a study of the illuminating apparatus was made, and it was concluded that the difficulty might be remedied by substituting for a certain plano-convex lens situated inside the axis of the telescope a lens which should be spherical on one side and cylindrical on the other. The best curves could be determined only by trial, and the first experimental lens made by Mr. M. E. Kahler did not prove sufficiently powerful. A second lens, furnished on January 19, 1897, has both its spherical and its cylindrical surface ground to a radius of 0.60 of an inch, and as it gave very good results it has been used ever since.

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During the month of June, 1897, a new clock pier of white Rutland marble, weighing 3.6 tons, and measuring 28 by 32 inches at the base, 24 inches square at the top, and 102 inches high was erected on the east side of the east transit circle room to take the place of the temporary pier which had stood on the west side of that room since June, 1892. At the same time three additional clock piers of Richmond granite, each weighing 2.3 tons, and measuring 25 by 30 inches at the base, 24 inches square at the top, and 75 inches high, were erected in the clock room, but the clocks have not yet been mounted upon any of these four piers.

On September 3, 1896, the outer disk on the head of the zenith distance micrometer of the transit circle was accidentally bent, and was repaired the next day by Mr. Kahler. On May 6, 1897, the same gentleman furnished two collimating eyepieces, one for the main telescope of the transit circle, and the other for the vertical collimator; and on May 20 he furnished dew caps for the objectives of the two horizontal collimators.

THE PRIME VERTICAL TRANSIT INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

This instrument has been used in connection with the meridian instrument Stackpole & Brother No. 1502 for determining variations of latitude and the constants of aberration and nutation, precisely as described in former reports, except that the stars 40 Aurigæ and 1450 Groombridge have been added in order to increase the possible number of observations at certain seasons of the year.

The number of observations obtained during the twelve months ending June 30, 1897, was as follows: With the prime vertical transit instrument, μ Andromedæ, 17; α Canum Venaticorum, 35; θ Aurigæ, 37; γ Bootis, 30; 40 Aurigæ, 4; Groombridge, 1450, 6; α Lyræ, 111. With the zenith telescope, α Lyræ, 120. Total 360 observations.

All observations made with the prime vertical transit instrument are copied on the reduction sheets up to June 30, 1897, reduced up to March 10, 1897, and transcribed for the printer up to October 15, 1896. The observations made with the zenith telescope are reduced up to October 20, 1896.

The entire series of observations made with the two instruments between July 24, 1893, and October 15, 1896, has been reduced, and the discussion of the observations for the latitude and variation of latitude at this observatory has been published in No. 404 of the Astronomical Journal. The value found for the latitude of the center of the clock room is $+ 38^\circ\ 55'\ 13.70'' \pm 0.10''$.

Both instruments have remained in excellent condition throughout the year. In the meridian instrument Stackpole & Brother No. 1502 no change whatever has been made, and in the prime vertical transit instrument only the mirrors employed in reading the striding level have been made a little wider. The latter change was effected on September 18, 1896, and about the same time there was purchased from Mr. Kahler, for the purpose of testing the pivots of the prime vertical transit, one spherometer caliper, of the kind described in the Monthly Notices of the Royal Astronomical Society (London), 1878, volume 38, pages 487–493.

THE TRANSIT CIRCLE STAR CATALOGUE.

[Prof. JOHN R. EASTMAN, United States Navy, in charge.]

In the preparation of this catalogue Professor Eastman has been assisted throughout the year by Mr. F. H. Parsons, temporarily

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employed for the purpose, and by Computer William M. Brown, who has devoted rather more than two-thirds of his time to the work. During the last twelve months the secular variations of the precessions have been computed and checked, and in order to guard against errors, these quantities, together with the positions of nearly all the stars, have been compared with the results obtained by other authorities. Several weeks were lost in correcting small systematic errors which were introduced into the star places in consequence of an unfortunate verbal statement got from the office of the American Ephemeris in 1896. The annual positions and catalogue places of the standard stars were completed several months ago, and the annual positions and catalogue places of the miscellaneous stars, together with the general introduction to the catalogues, are now nearly ready for the printer.

MISCELLANEOUS MATTERS.

During the year a large amount of work has been done toward the reduction of the photographic observations of the transit of Mercury of November 10, 1894. The greater part of this work is due to Professor Frisby, but Computer William M. Brown and Photographer Charles T. Fellows have also rendered effective services.

While the shutters on the various observing rooms work very satisfactorily under all ordinary circumstances, they have never been quite tight against rain storms with the wind at right angles to the openings in the roofs, and at such times a good deal of water penetrates to the instruments. Furthermore, many of the screws, which hold the zinc lining to the interior sides of the east transit circle room, have worked out, and consequently the sheets have become so much loosened that they present a very dilapidated appearance. These defects require attention.

During the year the following-named articles have been added to the permanent equipment of the Astronomical Department: July 6, 1896, a pair of 16-inch globes mounted on high stands. August 1, a Blickensderfer typewriter, for use in preparing the transit circle star catalogue. October 7, one 6-figure arithmometer.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics, U. S. N., Astronomical Director.

DEPARTMENT OF THE NAUTICAL ALMANAC.

Prof. Simon Newcomb was the Director of the Nautical Almanac from the beginning of the fiscal year until March 12, 1897, upon which date he was placed on the retired list, under the provisions of section 1444, Revised Statutes. Prof. William W. Hendrickson, by order of the Department, succeeded him. On June 30, 1897, Professor Hendrickson was detached and Prof. William Harkness was directed to assume the duties of Director of the Nautical Almanac in addition to his duties as Astronomical Director.

Professor Hendrickson submits the following report:

PRINTING.

The American Ephemeris for 1899 and the American Nautical Almanac for 1900 have been published. Owing to the introduction of new

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tables, constants, and other data in the Ephemeris for 1900, the printing of that volume has been delayed; 400 pages are now in print, and copy for the remainder is substantially ready for the printer.

Part I, Volume VIII of the Astronomical Papers, "A new determination of the precessional constant," is in press.

DISTRIBUTION.

During the fiscal year ending June 30, 1897, the sale and distribution of publications have been as follows:

Title.	Sold.	Distributed.	Public service.	Total.
American Ephemeris	509	494	568	1,571
American Nautical Almanac	1,958	6	302	2,266
Pacific Coaster's Almanac	1,254	3	35	1,292
Astronomical Papers	44	470	1	515

The proceeds of sales, amounting to $1,278.35, have, in compliance with law, been deposited in the Treasury to the account of the appropriation for printing and binding.

NEW TABLES OF THE PLANETS.

Upon the retirement of Prof. Simon Newcomb, in March, 1897, he was appointed to supervise the completion of the tables of the planets, so that this work has been under his direction during the year. Two skilled computers have been employed upon the tables of Uranus and Neptune and the revision of the theory of Mars. Additional computers have also been assigned to this work whenever they could be spared from other office duties.

EPHEMERIS OF THE FIXED STARS.

During the year a part of the office force has been constantly employed in the preparation of an International Catalogue of Standard Stars. The computations have been made in cooperation with the office of the British Nautical Almanac and the French Bureau des Longitudes.

Definitive mean places and annual variations for 1900 have been completed for all the stars given in the American Ephemeris, and these results have been used in the preparation of the volume for 1900. The completion of the catalogue, with the necessary checks and its preparation for the press, will probably occupy the greater portion of another year.

The adoption of new constants in the Ephemeris for 1900 made it necessary to prepare new tables for the reduction of mean to apparent places. These tables, 383 in number, have been completed and have been used in the preparation of the Ephemeris.

Very respectfully,

W. W. HENDRICKSON,
Professor of Mathematics, U. S. N., Director Nautical Almanac.

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DEPARTMENT OF NAUTICAL INSTRUMENTS.

Lieut. F. W. Kellogg, U. S. N., the head of this department, was detached July 8, 1896. The next officer in charge was Lieut. C. H. Lyman, U. S. N., from November 20, 1896, until his death, on January 28, 1897. Lieut. T. M. Brumby, U. S. N., was in charge from March 10 until June 1, 1897, when he was ordered on temporary duty at the Naval War College, Newport, R. I.

During the absence of Lieutenant Brumby, Lieutenant-Commander Goodwin has had charge of this department, in addition to his other duties. He reports as follows:

The classes of nautical instruments issued from the Observatory include sextants, octants, spyglasses, binocular glasses, protractors, stadimeters, reading glasses, drawing instruments, theodolites, measuring tapes, plane tables, psychrometers, thermometers, barometers, deck and boat clocks, clinometers, photographic outfits, parallel rulers, magnetic instruments, and other instruments issued to ships for navigating and surveying purposes.

Sextants and octants are inspected for accuracy of dimensions, form and fit of pivot, graduation of arc and vernier, optical performance of telescopes, shade glasses, eccentricity of limb, parallelism of faces of mirrors, weight, quality of workmanship, and conformity in other respects with the specifications.

Spyglasses and binoculars are inspected for power, field, clear aperture, focal distance, and mechanical construction, as set forth in the specifications for the several grades of glasses. Other instruments are inspected for conformity to detailed specifications that are attached to the requisitions calling for them.

The following instruments were rejected as failing to comply with the detailed specifications or required tests:

Stop watches (silver)	23
Three-arm protractor	1
Maximum and minimum thermometer	1
Aneroid barometers	5
Surveying sextants	5
High-grade sextant	1
Mercurial barometers	2
Spyglasses, low power	5
Chronometers	8

The cost of the various instruments purchased during the past fiscal year for issue is $15,546.31. The invoice value of the instruments issued to ships of the Navy during the year is $26,731.26.

The following instruments were received, inspected, and accepted during the year:

Chronometers	4
Binoculars:	
Day	54
Night	150
Spyglasses, low power	46
Sextants, high grade	16
Sextants, surveying	2
Octants	11
Sets, splines, and weights	20
Three-arm protractors	11
Psychrometers	20
Mercurial barometers	20
Clinometers	32

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Spyglasses, officer of the deck	125
T-squares	20
Deck clocks	50
Steel tapes	25
Thermometers, air and water	200
Stadimeters (Fiske)	5
Cases drawing instruments	20
Maximum and minimum thermometers	30
Captain's reading glasses	20
Navigator's dividers	20
Parallel rulers	95
Aneroid barometers	15

During the year 3,260 permits have been issued to visitors to visit the Observatory for a view of the heavens through the telescope, and a large additional number were issued by the Bureau of Equipment.

Very respectfully,

WALTON GOODWIN,
Lieutenant-Commander, U. S. N., General Storekeeper.

DEPARTMENT OF CHRONOMETERS AND TIME SERVICE.

Lieut. W. V. Bronaugh, U. S. N., was the head of this department until his detachment from the Observatory on February 20, 1897, and Assistant Astronomer H. M. Paul was in charge until March 31, 1897, when he was succeeded by Lieut. Chas. E. Fox, U. S. N., who has been assisted by Professor Paul since that date.

Lieutenant Fox makes the following report:

The present disposition of all chronometers belonging to the Navy is shown by the following table:

Kind.	In service afloat.	In service on shore.	In store at Mare Island.	At Observatory for issue.	Undergoing repairs.	Awaiting repairs.	Total.
Standards	144	10	35	35	7	.....	231
Hacks	49	21	10	5	1	.....	86
M. T. B. C	.....	5	1	1	.....	.....	7
Sidereal B. C	.....	3	3	3	1	.....	10
Sidereal	.....	1	1	.....	1	.....	3
Thermometric	.....	.....	.....	2	2	.....	4
Pocket	.....	.....	.....	5	.....	1	6

In addition to the above, there are in store 17 comparing watches for issue, 1 for repairs, and 2 for survey; 17 silver-case stop watches and 1 gold-case stop watch for issue; 27 maximum and minimum thermometers for issue, and 4 in use at the Observatory.

During the year 39 standard chronometers, 9 hacks, 9 stop watches, 11 comparing watches, and 11 thermometers have been issued to naval vessels.

The Observatory has received 15 standard chronometers, 2 hacks, and 2 comparing watches from naval vessels, and 1 standard chronometer, 1 hack, and 2 comparing watches from shore stations.

Two standard chronometers have been condemned as such and transferred to the hack list, and 1 hack, 1 comparing watch, and 2 thermometers have been condemned by survey and expended.

The annual trial of repaired chronometers commenced January 1, 1897, and was finished June 15, 1897. Twenty-six standard and 2 sidereal break-circuit chronometers were subjected to trial.

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During the same period 10 chronometers submitted for purchase were also subjected to trial.

The following tables give the results of these trials in detail:

Relative number.	Repaired by—	Chronometer number.	Maker.	Jan. 1 to Jan. 8.	Jan. 9 to Jan. 16.	Jan. 18 to Jan. 25.	Jan. 27 to Feb. 3.	Feb. 4 to Feb. 11.	Feb. 12 to Feb. 19.
	Time								
	Temperature, Fahrenheit			47.24	54.95	70.3	84.97	90.0	84.85
	Relative humidity, per cent			68.7	69.7	71.8	69.9	69.9	69.8
1	Negus	1776	T. S. & J. D. Negus	+0.910	+0.561	−0.249	−0.670	−0.386	−0.701
2	Bond	505	Wm. Bond & Son	−0.376	−1.189	−1.570	−0.884	−0.350	−1.059
3	Negus	1764	T. S. & J. D. Negus	+0.124	−0.653	−0.999	+0.044	+0.364	−0.237
4	do	1748	do	−0.019	+0.276	+0.287	+0.151	+0.400	+0.656
5	Bliss	2817	John Bliss & Co	+0.410	+0.204	−0.070	−0.456	−0.207	−0.523
6	do	2851	do	−0.376	−1.010	−1.427	−1.277	−1.171	−1.273
7	Negus	1444	T. S. & J. D. Negus	+1.339	+0.610	−0.177	+0.473	+0.900	−0.023
8	do	1519 S. B. C.	do	−0.106	−1.085	−1.067	−0.046	+0.630	−0.041
9	Bond	221	Wm. Bond & Son	−1.197	−1.367	−1.784	−1.849	−1.743	−1.951
10	Negus	1787	T. S. & J. D. Negus	−1.911	−1.939	−2.177	−1.634	−1.031	−1.451
11	Bliss	464	Usher & Cole	+0.339	−0.046	−0.356	+0.473	+0.971	+0.727
12	do	2792	John Bliss & Co	−0.233	−0.189	+0.287	+0.973	+1.543	+1.406
13	Heinrich	1007	H. H. Heinrich	+1.553	+0.419	+0.144	+1.223	+1.900	+1.334
14	Negus	1259	T. S. & J. D. Negus	+0.481	−0.328	−0.749	+0.651	+1.507	+0.656
15	do	1762	do	+1.410	+0.561	+0.109	+1.187	+1.900	+1.334
16	do	1636	do	+1.267	+0.490	+0.251	+1.223	+1.900	+1.406
17	do	1536 S. B. C.	do	+1.539	+0.918	+0.600	+2.419	+3.344	+2.707
18	do	1267	do	+1.731	+0.169	−0.784	−0.849	+0.150	−0.344
19	do	1452	do	+1.339	+0.276	−0.784	−0.491	+0.079	−0.237
20	do	1772	do	−0.876	−1.046	−0.999	−0.563	−1.171	−2.023
21	do	509	Wm. Bond & Son	+4.196	+3.490	+3.573	+4.366	+5.150	+4.691
22	do	1448	T. S. & J. D. Negus	−0.126	−0.974	−1.213	+0.223	+1.257	+0.799
23	Bliss	2381	John Poole	+1.410	+0.276	−0.927	−0.349	−0.064	−0.523
24	Bond	504	Wm. Bond & Son	−2.804	−1.581	−0.106	+0.187	−0.064	−0.273
25	Negus	1189	T. S. & J. D. Negus	+1.553	+0.526	+1.823	+3.080	+2.007	+2.870
26	do	1268	do	+0.660	−0.653	−1.999	−0.813	+0.543	+0.191
27	Bond	272	Wm. Bond & Son	+0.839	+0.776	+0.823	+0.973	+1.793	+2.191
28	Bliss	25568	M. F. Dent	+0.803	−0.653	−0.677	+0.473	−0.207	+0.477
1		1890	T. S. & J. D. Negus	−0.090	−1.081	−1.641	−0.777	−0.207	−0.880
2		1754	do	+3.017	+2.298	+1.930	+2.901	+3.579	+2.906
3		1872	do	+2.374	+1.454	+0.751	+1.651	+2.114	+1.191
4		1810	do	+3.910	+2.347	+1.037	+2.294	+2.757	+2.156
5		1021	H. H. Heinrich	−4.019	−4.453	−5.284	−4.491	−3.493	−4.201
6		994	do	−1.590	−1.831	−2.106	−1.920	−2.029	−3.201
7		1849	T. S. & J. D. Negus	+1.767	+0.490	−0.499	−0.456	−0.493	−1.166
8		1833	do	−0.019	−0.974	−2.034	−0.491	+0.543	−0.023
9		1874	do	+1.660	+1.133	+0.287	+0.901	+1.150	+0.370
10		1873	do	+2.017	+0.990	+0.251	+1.044	+1.293	+0.191

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Record of trial of repaired chronometers—Continued.

Relative number.	Repaired by—	Chronometer number.	Maker.	Feb. 21 to Feb. 28.	Mar. 3 to Mar. 10.	Mar. 13 to Mar. 20.	Mar. 23 to Mar. 30.	Mar. 30 to Apr. 6.	Apr. 6 to Apr. 13.
	Time								
	Temperature, Fahrenheit			69.81	54.57	45.1	66.55	66.15	68.72
	Relative humidity, per cent			68.6	65.2	72.4	53.4	49.0	51.7
1	Negus ..	1776	T. S. & J. D. Negus....	—0.413	+0.133	+0.691	—0.049	—0.026	—0.247
2	Bond ...	505	Wm. Bond & Son.....	—1.699	—1.117	+0.227	—1.691	—1.561	—1.926
3	Negus ..	1764	T. S. & J. D. Negus....	—0.770	—0.331	+0.691	—1.227	—1.383	—1.426
4	...do	1748	.....do.....	+0.587	+0.919	+0.727	+0.951	+1.117	+1.110
5	Bliss....	2817	John Bliss & Co.....	—0.377	—0.189	+0.299	+0.059	+0.331	+0.217
6	...do	2851	.....do.....	—0.913	—0.331	+0.334	—0.441	—0.811	—1.069
7	Negus ..	1444	T. S. & J. D. Negus....	—0.377	+0.419	+2.120	—0.370	—0.526	—0.819
8	...do	1519 S. B. C.	.....do.....	—0.860	—0.390	+0.386	—0.894	—0.806	—0.804
9	Bond ...	221	Wm. Bond & Son.....	—1.877	—1.724	—1.666	—1.299	—0.919	—1.069
10	Negus ..	1787	T. S. & J. D. Negus....	—2.449	—1.974	—1.916	—2.584	—2.597	—2.747
11	Bliss....	464	Usher & Cole.....	+0.016	+0.204	—0.309	—0.084	—0.097	—0.176
12	...do	2792	John Bliss & Co.....	+0.766	+0.454	+0.156	+0.380	+0.296	+0.217
13	Heinrich	1007	H. H. Heinrich.....	+0.623	+1.240	+2.191	+0.594	+0.546	+0.539
14	Negus ..	1259	T. S. & J. D. Negus....	—0.341	—0.010	+0.834	—0.584	—0.776	—0.819
15	...do	1762	.....do.....	+0.873	+1.597	+2.549	+0.844	+0.510	+0.146
16	...do	1636	.....do.....	+0.980	+1.776	+2.049	+1.309	+1.296	+1.253
17	...do	1536 S. B. C.	.....do.....	+1.533	+1.540	+2.384	+1.071	+1.086	+1.017
18	...do	1267	.....do.....	—0.056	+1.133	+2.906	—0.441	—0.776	—1.140
19	...do	1452	.....do.....	+0.051	+1.419	+2.691	—0.156	—0.347	—0.676
20	...do	1772	.....do.....	—1.949	—0.724	—0.666	—1.763	—1.490	—1.569
21	...do	509	Wm. Bond & Son.....	+4.373	+4.740	+6.263	+2.987	+2.867	+2.789
22	...do	1448	T. S. & J. D. Negus....	+0.087	+0.133	+0.763	—0.120	—0.169	—0.069
23	Bliss ...	2381	John Poole.....	—0.520	+1.454	+2.191	—0.084	—0.383	—0.604
24	Bond ...	504	Wm. Bond & Son.....	—0.591	—2.903	—3.666	—1.941	—2.204	—2.033
25	Negus ..	1189	T. S. & J. D. Negus....	+1.873	+2.454	+3.299	+1.630	+1.903	+1.789
26	...do	1268	.....do.....	—0.449	+0.633	+1.906	—0.691	—0.169	—0.354
27	Bond ...	272	Wm. Bond & Son.....	+1.480	+2.347	+2.906	+1.523	+1.260	+1.181
28	Bliss ...	25568	M. F. Dent.....	+1.123	+1.811	+2.441	+0.558	+0.760	+0.360
1	.....	1890	T. S. & J. D. Negus....	—1.591	—1.046	—0.023	—1.620	—1.811	—1.854
2	.....	1754	.....do.....	+2.230	+2.847	+3.513	+2.559	+2.474	+2.431
3	.....	1872	.....do.....	+0.551	+1.669	+2.441	+0.380	+0.403	+0.289
4	.....	1810	.....do.....	+1.909	+2.454	+3.727	+1.166	+1.224	+0.967
5	.....	1021	H. H. Heinrich	—5.341	—5.367	—4.880	—5.370	—5.311	—5.283
6	.....	994	.....do.....	—3.091	—2.439	—1.630	—3.727	—3.097	—3.069
7	.....	1849	T. S. & J. D. Negus....	—1.449	+0.026	+1.191	—0.763	—0.561	—0.783
8	.....	1833	.....do.....	—1.127	—0.260	+0.584	—1.370	—1.383	—1.461
9	.....	1874	.....do.....	—0.591	—0.331	+0.084	—1.084	—1.240	—1.283
10	.....	1873	.....do.....	—1.199	—1.153	—0.451	—1.334	—1.311	—1.390

Relative number.	Repaired by—	Chronometer number.	Maker.	Apr. 13 to Apr. 20.	Apr. 20 to Apr. 27.	Apr. 27 to May 4.	May 4 to May 11.	May 11 to May 18.	May 18 to May 25.	May 25 to June 1.
	Time									
	Temperature, Fahrenheit			70.17	68.66	69.46	72.67	71.01	68.39	68.37
	Relative humidity, per cent			52.6	52.4	55.4	56.7	61.2	66.00	62.0
1	Negus	1776	T. S. & J. D. Negus	—0.253	—0.297	—0.303	—0.414	—0.404	—0.344	—0.301
2	Bond .	505	Wm. Bond & Son .	—2.003	—1.797	—2.017	—1.986	—2.261	—2.344	—2.444
3	Negus	1764	T. S. & J. D. Negus	—1.574	—1.619	—1.553	—1.414	—1.654	—1.594	—1.659
4	...do ..	1748	.....do	+0.997	+0.881	+0.840	+0.729	+0.489	+0.620	+0.454
5	Bliss .	2817	John Bliss & Co..	—0.110	—0.333	—0.410	—0.450	—0.547	—0.380	—0.444
6	...do ..	2851	.....do	—1.074	—1.119	—1.231	—1.200	—1.047	—1.094	—1.159
7	Negus	1444	T. S. & J. D. Negus	—0.789	—0.869	—0.946	—0.914	—0.869	—1.094	—1.016
8	...do ..	1519 S. B. C.	.....do	—0.771	—0.889	—0.930	—0.933	—1.173	—1.231	—1.140
9	Bond .	221	Wm. Bond & Son .	—0.896	—0.797	—0.017	+0.300	+0.274	+0.191	+0.270
10	Negus	1787	T. S. & J. D. Negus	—2.610	—2.940	—2.874	—2.986	—3.154	—3.309	—3.230
11	Bliss .	464	Usher & Cole.....	—0.074	—0.119	—0.089	+0.014	—0.119	—0.201	—0.230
12	...do ..	2792	John Bliss & Co..	+0.140	—0.154	—0.196	—0.093	+0.167	+0.156	+0.199
13	Hein-rich.	1007	H. H. Heinrich....	+0.604	+0.596	+0.661	+0.836	+0.846	+0.763	+0.806
14	Negus	1259	T. S. & J. D. Negus	—0.753	—0.869	—0.910	—0.700	—0.797	—1.023	—1.087
15	...do ..	1762	.....do	+0.211	+0.167	+0.483	+0.586	+0.774	+0.691	+0.556
16	...do ..	1636	.....do	+1.247	+1.203	+1.197	+1.157	+0.989	+1.013	+0.877
17	...do ..	1536 S. B. C.	.....do	+1.193	+0.969	+1.071	+1.173	+1.150	+1.089	+1.039
18	...do ..	1267	.....do	—1.217	—1.154	—1.160	—1.236	—1.047	—0.951	—1.087
19	...do ..	1452	.....do	—0.574	—0.654	—0.803	—1.057	—0.869	—0.809	—0.730
20	...do ..	1772	.....do	—1.574	—1.583	—1.589	—1.700	—1.797	—1.809	—1.873

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Record of trial of repaired chronometers—Continued.

Relative number.	Repaired by—	Chronometer number.	Maker.	Time	Apr. 13 to Apr. 20.	Apr. 20 to Apr. 27.	Apr. 27 to May 4.	May 4 to May 11.	May 11 to May 18.	May 18 to May 25.	May 25 to June 1.
				Temperature, Fahrenheit	70.17	68.66	69.46	72.67	71.01	68.39	68.37
				Relative humidity, per cent	52.6	52.4	55.4	56.7	61.2	66.00	62.0
21	Negus	509	Wm. Bond & Son		+2.819	+2.810	+2.911	+2.800	+2.989	+3.049	+3.127
22	...do	1448	T. S. & J. D. Negus		—0.003	—0.047	—0.053	+0.086	+0.060	—0.166	—0.087
23	Bliss	2381	John Poole		—0.824	—0.833	—0.767	—0.914	—0.690	—0.773	—0.730
24	Bond	504	Wm. Bond & Son		—1.789	—2.083	—2.374	—1.629	—1.547	—2.344	—2.301
25	Negus	1189	T. S. & J. D. Negus		+1.890	+1.774	+1.911	+1.907	+1.631	+1.727	+1.699
26	...do	1268	...do		—0.360	—0.440	—0.731	—0.843	—0.797	—0.809	—0.659
27	Bond	272	Wm. Bond & Son		+0.676	—0.011	—0.231	—0.700	—0.869	—0.951	—0.337
28	Bliss	25568	M. F. Dent		+0.283	+0.203	+0.090	—0.021	—0.154	—0.451	—0.480
1	.....	1890	T. S. & J. D. Negus		—1.931	—2.154	—2.160	—2.129	—2.226	—2.273	—2.373
2	.....	1754	...do		+2.461	+2.310	+2.590	+2.586	+2.310	+2.263	+2.234
3	.....	1872	...do		+0.140	+0.131	—0.017	—0.129	—0.190	—0.309	—0.409
4	.....	1810	...do		+0.961	+0.881	+0.876	+0.907	+1.024	+1.120	+0.984
5	.....	1021	H. H. Heinrich		—5.253	—5.226	—5.231	—4.807	—4.333	—4.773	—4.909
6	.....	994	...do		—3.110	—3.190	—3.517	—3.450	—3.476	—3.487	—3.408
7	.....	1849	T. S. & J. D. Negus		—0.753	—0.833	—0.839	—0.843	—0.976	—1.094	—1.230
8	.....	1833	...do		—1.610	—1.797	—1.910	—2.021	—2.011	—2.273	—2.623
9	.....	1874	...do		—1.646	—1.726	—1.874	—1.771	—2.011	—2.309	—2.266
10	.....	1873	...do		—1.717	—2.154	—2.089	—2.236	—2.404	—2.666	—2.659

Relative number.	Repaired by—	Chronometer number.	Maker.	Time	June 1 to June 8.	June 8 to June 15.	Temperature of compensation.	Temperature constant.	First trial number.	Final trial number.
				Temperature, Fahrenheit	69.99	73.36				
				Relative humidity, per cent	70.0	71.5				
1	Negus	1776	T. S. & J. D. Negus		—0.296	—0.479	95.16	+0.00068	9.617	9.903
2	Bond	505	Wm. Bond & Son		—2.510	—2.443	68.64	+0.00252	8.130	10.853
3	Negus	1764	T. S. & J. D. Negus		—1.474	—1.514	67.32	+0.00261	10.092	10.884
4	...do	1748	...do		+0.419	+0.236	81.52	+0.00028	9.663	11.445
5	Bliss	2817	John Bliss & Co		—0.689	—0.871	—20.73	—0.00009	8.746	11.535
6	...do	2851	...do		—1.260	—1.229	81.64	+0.00085	9.992	12.095
7	Negus	1444	T. S. & J. D. Negus		—0.939	—0.979	71.41	+0.00278	13.055	14.495
8	...do	1519 S. B. C.	...do		—1.279	—1.351	65.09	+0.00247	13.345	14.533
9	Bond	221	Wm. Bond & Son		+0.204	—0.086	82.62	+0.00046	4.034	14.564
10	Negus	1787	T. S. & J. D. Negus		—3.296	—3.479	67.09	+0.00249	12.594	15.300
11	Bliss	464	Usher & Cole		—0.331	—0.336	66.01	+0.00226	14.937	15.353
12	...do	2792	John Bliss & Co		+0.204	+0.521	41.93	+0.00063	13.764	15.402
13	Heinrich	1007	H. H. Heinrich		+0.847	+0.950	67.33	+0.00296	16.934	17.199
14	Negus	1259	T. S. & J. D. Negus		—1.010	—0.907	65.77	+0.00345	16.878	17.644
15	...do	1762	...do		+0.490	+0.450	68.83	+0.00299	22.407	24.270
16	...do	1636	...do		+0.919	+0.950	68.72	+0.00268	24.442	24.918
17	...do	1536 S. B. C.	...do		+1.080	+1.290	63.57	+0.00358	28.731	28.933
18	...do	1267	...do		—1.010	—0.979	80.56	+0.00193	28.955	30.568
19	...do	1452	...do		—0.796	—0.836	77.46	+0.00263	29.632	30.754
20	...do	1772	...do		—1.939	—2.050	73.86	+0.00168	30.842	31.754
21	...do	509	Wm. Bond & Son		+3.133	+3.021	65.40	+0.00155	34.742	35.516
22	...do	1448	T. S. & J. D. Negus		—0.154	+0.093	64.13	+0.00272	35.550	35.706
23	Bliss	2381	John Poole		—0.760	—1.014	75.01	+0.00412	40.395	41.995
24	Bond	504	Wm. Bond & Son		—2.189	—1.907	80.48	—0.00342	42.251	45.473
25	Negus	1189	T. S. & J. D. Negus		+1.847	+1.486	55.69	+0.00174	50.313	53.625
26	...do	1268	...do		—0.724	—0.764	70.90	+0.00467	64.894	67.422
27	Bond	272	Wm. Bond & Son		—1.010	—1.764	69.66	+0.00184	44.046	67.472
28	Bliss	25568	M. F. Dent		—0.867	—0.907	70.32	+0.00353	72.391	78.394
1	.....	1890	T. S. & J. D. Negus		—2.403	—2.407	68.51	+0.00296	9.404	11.017
2	.....	1754	...do		+2.169	+2.200	67.79	+0.00286	12.388	13.319
3	.....	1872	...do		—0.439	—0.550	70.47	+0.00369	18.996	20.472
4	.....	1810	...do		+0.883	+0.986	70.62	+0.00369	20.676	21.105
5	.....	1021	H. H. Heinrich		—5.224	—4.943	66.59	+0.00298	21.837	25.917
6	.....	994	...do		—3.117	—3.229	76.32	+0.00109	26.333	30.019
7	.....	1849	T. S. & J. D. Negus		—1.296	—1.336	75.68	+0.00303	29.386	30.308
8	.....	1833	...do		—2.653	—2.764	68.65	+0.00504	41.253	46.005
9	.....	1874	...do		—2.296	—2.086	68.52	+0.00296	42.612	46.552
10	.....	1873	...do		—2.689	—2.586	66.30	+0.00329	103.647	109.240

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During the year 24 comparing and 15 stop watches have been subjected to trial, of which 11 comparing and 10 stop watches were purchased.

Thirty maximum and minimum thermometers have also been purchased.

The performance of the three clocks in this department has been satisfactory, and the mean time of noon (seventy-fifth meridian) as determined by observation has been sent out on every day of the year except Sundays. The average error for the year of the noon signals was 0.23 second.

The reports from branch hydrographic offices continue to show that the signal is received with a fair degree of regularity.

Mr. M. E. Porter, computer, has done excellent work as assistant in this office.

Very respectfully,

CHAS. E. FOX,
Lieutenant, U. S. N.,
Head of Department Chronometers and Time Service.

DEPARTMENT OF MAGNETISM AND METEOROLOGY.

Mr. J. N. James, electrician, has had charge of this department during the year. The regular routine observations have been made. Owing to the proximity of the electric railway on the Tennallytown road, the readings of the self-registering instruments have been greatly disturbed, and their value is very questionable.

Unless some means can be devised for protecting these instruments from local disturbances, the work in this department will hardly accomplish the purposes for which they were installed. I shall bring to the attention of my successor the difficulties that have been encountered, with the hope that they may be overcome.

LIBRARY.

Assistant Librarian William D. Horigan has direct charge of the library, under the general supervision of the library committee.

	Volumes.	Pamphlets.	Total.
Contents of library July 1, 1896	15,456	3,304	18,760
Accessions	580	107	687
Contents July 1, 1897	16,036	3,411	19,447

Of the accessions, 292 were received as exchanges and 395 were purchased.

BUILDINGS AND GROUNDS.

Satisfactory progress has been made in the improvements of the grounds and roads.

The two new houses erected for residences of observers are now occupied.

The buildings are generally in good condition.

Leaks through walls on the north side of the Superintendent's residence have developed during recent storms to a degree that will necessitate a careful inspection and such repairs as may prove to be necessary for its preservation.

Very respectfully,

R. L. PHYTHIAN,
Commodore, U. S. N., Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department, Washington D. C.

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REPORT

OF THE

SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1898.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1898.

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REPORT

OF THE

SUPERINTENDENT OF THE UNITED STATES NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1898.

SIR: I have the honor to submit the annual report of the operations of the United States Naval Observatory for the fiscal year ending June 30, 1898.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

The report of the astronomical director is as follows:

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1898.

SIR: In compliance with paragraph 23 of the regulations for the Government of the United States Naval Observatory, I have the honor to submit the following report concerning the operations of the astronomical department for the fiscal year ending June 30, 1898.

THE 26-INCH EQUATORIAL TELESCOPE.

[Prof. STIMSON J. BROWN, U. S. N., in charge.]

As usual, this instrument has been employed almost exclusively on faint and difficult objects, which could not well be reached by smaller telescopes. The work accomplished during the year was as follows:

D'Arrest's periodic comet, 1897 II= *a* 1897, was sought for on almost every favorable occasion from July 9 to September 3, 1897, but it was generally difficult to see on account of its position in the southwestern sky, which is illuminated by the electric lights of the city, and only nine observations were obtained.

Giacobini's comet, *g* 1898, was observed on June 21, 1898, but as it was visible in the 5-inch finder its further observation was left to the 12-inch equatorial telescope.

The observations of the relative positions of Titan and Iapetus during the years 1894, 1895, and 1896 gave for the mass of Saturn 1: (3491.8 ± 0.81), and as that falls about halfway between the value found by Prof. Asaph Hall and the group of values found, respectively, by Bessel, H. Struve, and A. Hall, jr., it tends to emphasize the difficulty of avoiding systematic errors in observing satellites. As the latter group of values is supported by the result obtained by Dr. George W. Hill from the perturbations of Jupiter by Saturn, it has been surmised that the observations of the relative positions of Titan and Iapetus may have been vitiated by the superior brightness of the former, and therefore it was decided to attempt a determination of the mass of Saturn from observations of the relative positions of Rhea and Iapetus. That work was begun on May 16, 1898.

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Observations of the satellite of Neptune were attempted on almost every possible occasion from October 13, 1897, to March 13, 1898, and 41 complete measurements of position angle and distance were obtained.

In order to determine correct formulæ for the semidiameters of Mercury and Venus it is desirable to have measurements of these planets in all parts of their orbits, and to that end a watch has been kept upon them, and measurements have been made with the filar micrometer whenever the seeing was sufficiently good. During the year the diameter of Venus has been satisfactorily determined on 16 occasions and that of Mercury on 3 occasions, the mean results at distance unity being for the diameter of Venus 17.47″ and for the diameter of Mercury 7.21″.

Observations of difficult double stars have been continued on the same general plans as in previous years, and, as usual, the work has been much impeded by the paucity of nights on which high-magnifying power could be satisfactorily used. At the request of Prof. S. W. Burnham, a large number of close doubles discovered by him were included in our observing list, and observations were begun on them in October, 1897. Most of these stars require a power of at least 900 to divide them satisfactorily, but out of fifty-four nights, during which 130 pairs were observed, there were only ten nights on which a power of 888 could be used, and on only three of these ten did the favorable conditions last so long as two or three hours.

During the period May 3 to June 8, 1898, 11 observations were made with the spectroscope to determine the focal curve of the 26-inch telescope. The investigation is not yet complete, but the minimum focal distance was found to be at, or very near to, the spectral line E, and the coordinates of the curve at the other principal lines were as follows:

	Inches.		Inches.
B	0.197	b	0.012
C	.146	F	.142
D	.032	4340	0.918
E	0.000	G	1.233

The office work has been mainly confined to current reductions, together with the revision and preparation for publication of the Titan and Iapetus observations. In addition to this the observations of the satellites of Mars, made in November and December, 1896, have been reduced, and from them, in combination with the observations made at the Lick Observatory, elements have been derived for the orbits of Deimos and Phobos.

Throughout the year much of Professor Brown's time has been absorbed by the work of inspecting and surveying instruments belonging to the nautical branch of the Observatory, and, on account of the detachment of officers for the war with Spain, since May 1 he has acted as storekeeper, and his days have been almost entirely occupied by the inspection and issue of nautical instruments to the Navy. He has also made an investigation and report upon the present condition of our magnetic observatory, including a comparison of its methods and results with those of similar establishments in other countries.

On November 11, 1897, a little water condensed between the lenses composing the object glass of the 26-inch telescope, and the next day Professor Brown removed the objective from its cell, cleaned it, and restored the lenses to their normal condition. With that exception the 26-inch telescope has remained in excellent order throughout the year and its polar axis has maintained its adjustment with very great constancy. The observations made on November 27, 1897, showed that the coordinates of the latter, relatively to the pole of the heavens, were then $\xi = +1'\,16''$, $\eta = +1'\,44''$.

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On June 30, 1897, verniers and index marks were painted on the pointers of the coarse right ascension and declination setting circles of the 26-inch telescope, these adjuncts having been wanting up to that time. December 7, 1897, auxiliary gears were added to the slow-motion handles at the eye end of the telescope, in order to reduce their speed and thus facilitate bringing stars accurately upon the slit of a spectroscope. May 24, 1898, a drip cock was inserted in the oil box which surrounds the screw for driving the polar axis of the telescope, that being necessary to facilitate getting rid of the water which condenses on the mounting of the telescope in damp weather and runs down into the oil box.

After being altered by Messrs. Warner & Swasey, as explained in my last annual report, the chronograph constructed by Messrs. Alvan Clark & Sons in 1875, and employed with the 26-inch telescope in the old Naval Observatory, was remounted here and made ready for use in October, 1897.

In winter, to prevent the hydraulic rams which work the elevating floor from freezing, it is sometimes necessary to drain all the water from them. In such cases they become filled with air, and when the water is again turned on the air gets trapped in the tops of the rams and has heretofore given much trouble by causing the floor to move in an irregular and jerky manner. This defect was remedied on May 24, 1898, by the insertion of a small relief cock in the top of each ram.

THE 12-INCH EQUATORIAL TELESCOPE.

[Prof. EDGAR FRISBY, U. S. N., in charge.]

This instrument was employed during the year in observing comets minor planets, occultations of stars by the moon, eclipses of Jupiter's satellites, and in determining the positions of a few faint stars for the 26-inch equatorial telescope. The work done was as follows:

Thirty-one observations of asteroids were made, namely: 1 of Hebe (6), 5 of Iris (7), 3 of Parthenope (11), 2 of Themis (24), 6 of Danäe (61), 2 of Cybele (65), 1 of Ophelia (171), 7 of Prokne (194), 1 of Unitas (306), and 3 of Eucrate (247).

Perrine's comet, *b* 1898, was observed twelve times.

Coddington's comet, *c* 1898, was observed three times.

Perrine's comet, *e* 1898, was observed once.

Giacobini's comet, *g* 1898, was observed once.

The positions of nine miscellaneous stars were observed for use in connection with the work of the 26-inch telescope.

Four occultations of stars by the moon and fourteen eclipses of Jupiter's satellites were observed.

The above observations are all completely reduced, and the results of the observations of comets have been printed in the Astronomical Journal.

For several years past the 12-inch telescope has been used for the exhibition of celestial objects to visitors on every Tuesday and Thursday evening, weather permitting, and that practice was continued until October 12, 1897; but since then the admission of the public has been limited to Thursday evenings. As usual, permits for these evenings have been issued both by the Observatory and by the Bureau of Equipment. I do not know the total number granted, but during the period covered by this report 1,394 names were entered in the visitors' book, and there were doubtless a considerable number of visitors who did not register.

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The alterations and repairs made on the 12-inch telescope during the year just closed were as follows: As the electric lamps for giving bright webs on a dark ground in the field of the large filar micrometer had never worked well, a new arrangement of them was devised by the astronomical director. The necessary changes for bringing it into use were completed on August 18, 1897, and since that date the illumination of both the right ascension and declination webs has been completely under the control of the observer and entirely satisfactory. On October 28, 1897, a 14-volt incandescent electric lamp of 10-candle-power was installed immediately above the automatic dials which indicate the pointing of the telescope, so as to render them visible independently of the general illumination of the room. The contact springs on the polar axis, for transmitting the electric current which lights the circles and field of the telescope, having proved altogether too delicate, a new and more substantial set were inserted on November 4, 1897, and at the same time the declination clamp of the telescope was repaired by securing the rod from the handle more firmly to the Hooke's joint which connects it with the clamping screw. On March 7, 1898, a tooth in one of the beveled pinions of the right ascension quick-motion train was found broken. The pinion in question was of cast iron, and in order to diminish the risk of such an accident recurring in the future, it was replaced by a steel pinion, which was inserted on May 2.

THE 9.14-INCH TRANSIT CIRCLE.

[Assistant Astronomer Aaron N. Skinner, in charge.]

In the work with this instrument Assistant Astronomer Skinner has been aided, for the periods specified, by the following-named gentlemen: Assistant Astronomer Theo I. King, and Computers F. B. Littell, E. A. Boeger, and G. K. Lawton throughout the year, except that on several occasions Mr. Boeger was temporarily detached for periods of a week or more to aid in inspecting nautical instruments; Computer Minott E. Porter from October 11, 1897. Computer William M. Brown has aided throughout the year in observing, but not in computing.

As the observations for the German Astronomical Society's zone, lying between 13° 50′ and 18° 10′ of south declination, were substantially completed in 1896, while the reductions are still far from finished, it was thought best to limit the work of the transit circle during the present year to observations of the Sun, Moon, and planets, together with such stars as were wanted for special purposes, and the minimum number of ephemeris stars necessary for determining instrumental constants.

The observations actually made during the twelve months ending June 30, 1898, are as follows:

Stars required for completing the zone −13° 50′ to −18° 10′, 2; zero stars for zones, 11; American Ephemeris stars, 2,902; miscellaneous stars, 17; Sun, 186; Moon, 184; Mercury, 106; Venus, 148; Jupiter, 40; Saturn, 44; Uranus, 41; Neptune, 50; Hebe (6), 15; Parthenope (11), 13; Amphitrite (29), 7; Danäe (61), 5; Eucrate (247), 7; total, 3,778.

In compliance with special requests the positions of 16 stars, from the zone −13° 50′ to −18° 10′, have been reduced and furnished to Dr. J. Bauschinger, of Berlin, Germany, and the results of certain observations of the major planets have been furnished to the office of the American Ephemeris and Nautical Almanac, as follows: Mars, 14 observations made in 1894; Jupiter, 2 observations in 1894 and 2 observations in 1895; Uranus, 8 observations in 1895, 2 observations in 1896,

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and 56 observations in 1897; Neptune, 2 observations in 1894, 2 observations in 1895, 28 observations in 1896, 55 observations in 1897, and 16 observations in 1898.

The reductions of the observations of the sun, moon, and planets are based upon the star places given in the American Ephemeris, and are intended to be wholly differential. During the current year these reductions have been completed throughout the period extending from October 10, 1894, to February 23, 1898, and are very nearly completed through April 7, 1898, but after the latter date they have not been begun. The chronograph sheets have been read off through May 16, 1898.

Owing to the necessity of employing the entire computing force on the reduction of the sun, moon, and planet observations, very little work has been done on the zone observations during the current year. That accomplished was as follows: In right ascension the reduction from the date of observation to 1900 has been interpolated from the tables through zone 64 and checked through zone 55. In declination the reduction from date to the beginning of the year of observation has been interpolated from the tables through zone 59 and checked through zone 28. The total number of zones is 184, and the work necessary for their completion would probably occupy three computers about a year. It is as follows: The preparation of the reduction tables for zones 165 to 184, inclusive; the interpolation in declination from the beginning of the year of observation to 1900 for zones 1 to 59, and from the date of observation to 1900 in zones 60 to 184; the assembling of the observations in order of right ascensions and the taking of the means; the computation of the annual precessions and secular variations, both in right ascension and in declination.

On January 6, 1898, a new open-air thermometer, Henry J. Green, No. 3881, was brought into use for determining the refractions to be employed in reducing observations made with the 9.14-inch transit circle. Its scale is divided to single degrees, from $-12°$ F. to $+126°$ F., and the mean length of 1 degree is 0.080 inch.

The cases of the transit circle counting clock by Parkinson & Frodsham, Change alley, and of the prime vertical clock, by Charles Frodsham, 84 Strand, London, having become much injured on account of deterioration of the glue from fifty years' exposure in the observing rooms, they were thoroughly repaired by Mr. A. E. Wurdeman in July, 1897.

The mounting of the clocks upon the new piers described in my last annual report was much delayed by the ill health of Mr. Gardner, the Observatory instrument maker. There are five piers in the clock room, and upon four of them clocks were mounted and brought into use on the following dates, namely: On July 21.8, 1897, the sidereal clock, E. Howard & Co., Boston, Mass., No. 404, which is the working standard used with the 9.14-inch transit circle; on July 28, 1897, the mean time clock, Parkinson & Frodsham, Change alley, London, No. 611, which had previously been running on sidereal time, its pendulum having been screwed up for that purpose; on August 4, 1897, the standard sidereal clock, Kessels, Altona, No. 1324, and on November 8, 1897, the sidereal clock, Charles Frodsham, 84 Strand, London.

The clock room is provided with steam-heating apparatus, and its temperature is never allowed to vary rapidly; but, as an additional precaution, on January 24–25, 1898, each of the four clocks just mentioned was inclosed in a small wooden house, measuring 3 feet 6 inches by 4 feet on the floor, and 7 feet 1 inch high, provided with a

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door having a glass window, through which the face of the clock can be seen without opening the door itself.

Ever since the occupation of the present clock room, much difficulty has been experienced in keeping the clocks mounted therein free from rust during the winter months. The source of this evil was finally found in the steam-heating apparatus, whose relief valves were so arranged that they frequently permitted steam to escape into the room, and thus kept the atmosphere saturated with moisture. Last January this was remedied by equipping these valves with pipes, which now deliver the waste steam outside the building.

The mounting of the 9.14-inch transit circle counting clock, by Parkinson & Frodsham, Change alley, upon the new marble pier on the east side of the east transit circle room, was completed on November 16, 1897, and the clock was immediately brought into use.

THE NEW 6-INCH STEEL TRANSIT CIRCLE.

This instrument was built by Messrs. Warner & Swasey, of Cleveland, Ohio, in pursuance of their contract dated March 20, 1893, under the immediate supervision of the present Astronomical Director, and in accordance with minutely detailed specifications and instructions furnished by him. In order to reduce the effects of flexure and changes of temperature to a minimum, it is constructed entirely of steel, the two halves of the telescope tube having each been turned out of a solid steel bar 11 inches in diameter and 28 inches long and the interior both of the telescope tube, the cube, and the axis having been machined out so as to give every part precisely the thickness it was intended to have.

The telescope has a clear aperture of 6 inches, with a focal distance of 72 inches, and is provided with bright and dark field illumination, a system of right ascension and declination wires similar to those in the 9.14-inch transit circle, a right ascension micrometer, a zenith distance micrometer, and four eyepieces magnifying, respectively, 72, 102, 144, and 204 diameters, together with all necessary sunshades and nadir caps. The axis is 36 inches long, the pivots are of hardened steel, 2.24 inches in diameter, and the clamp is provided with double joints so as to preclude the possibility of its transmitting any pressure to the pivots. There are two steel circles, each 26.75 inches in diameter, divided upon silver to every two minutes, and each read by four micrometer microscopes. The graduation is figured at every degree, with numbers small enough to be read both in the setting and in the micrometer microscopes, and for determining the errors of graduation two auxiliary microscopes are provided. The illumination of the circles and of the field of the telescope is derived from a common source, which can be instantly changed from gas to electric light by the mere pushing of a slide. The adjustments for level and azimuth are of the most solid description, and so arranged that they can always be brought into a condition which is equivalent to their complete elimination. A hanging level, several pieces of special testing apparatus, a reversing carriage, and a movable mercury basin for reflection observations of stars are also provided.

One vertical and two horizontal collimators are mounted in connection with this instrument, each having a clear aperture of 4.05 inches, The vertical collimator has a focal length of 51.5 inches, and is provided with a collimating cap, while the two horizontal collimators have a focal length of 48 inches, and are provided with a striding level, and stops so arranged that the collimators can be rotated accurately through

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arcs of 90° in order to eliminate collimation both in a vertical and in a horizontal direction.

The 6-inch transit circle is mounted in the west transit circle house, whose interior was left unfinished when the building was erected. The marble piers for the transit circle and collimators were put in place in June, 1896. The wooden floor beams were placed on the iron girders; the iron tracks for the reversing carriage and mercury basin, together with the turntable, were put in, and the lower floor was laid in November, 1897. The transit circle and collimators were set up in December, 1897, the upper floor was laid in March, 1898, and the curtains for protecting the instrument during observations of the sun were put up in May, 1898. A number of fittings have yet to be provided before the instrument will be ready for use, but they are being pushed forward as rapidly as possible.

THE NEW 5-INCH STEEL ALTAZIMUTH INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

This instrument was built by Messrs. Warner & Swasey, of Cleveland, Ohio, in pursuance of a requisition dated November 7, 1894, under the immediate supervision of the present Astronomical Director, and in accordance with minutely detailed instructions furnished by him. It is intended to be used either as an altazimuth instrument, as a vertical circle, or as a zenith telescope; is constructed of steel upon the same principles as the 6-inch transit circle, and the details of its circles, microscopes, and clamps are, so far as possible, identical with those of that instrument. The telescope has a clear aperture of 5.02 inches, with a focal length of 50 inches, and is provided with two latitude levels for use in accordance with Talcott's method. It has bright field illumination, 9 right-ascension wires, a zenith-distance micrometer, 8 positive eyepieces—namely, 4 Frauenhofer's and 4 Kellner's, magnifying, respectively, 49, 70, 100, and 148 diameters—and 1 long diagonal eyepiece magnifying 70 diameters. The horizontal axis of the telescope is 25.0 inches long, with pivots 1.87 inches in diameter. The instrument has 1 horizontal and 1 vertical circle, both of steel, 24 inches in diameter, and both divided upon silver to every two minutes. The horizontal circle is read by 3 micrometer microscopes, the vertical circle is read by 4 micrometer microscopes carried upon an alidade provided with 2 levels for determining the position of the zenith point, and there are 2 auxiliary microscopes which can be used for investigating the graduation errors of either circle. The field of view of the telescope, the alidade levels, and all the circle microscopes are illuminated by a single lamp, which is carried by the instrument and reverses with it.

The altazimuth instrument is mounted, approximately, 273 feet = 2.70″ north and 157 feet = 0.132^s west of the center of the clock room, in a circular wooden building, 11 feet 10 inches in diameter, covered by a revolving dome having a slit 28 inches wide extending through an arc of 135°. The pier which carries the instrument is of brick, 48 inches square at the bottom, and resting upon a mass of concrete 6 feet in diameter, whose base is 4 feet below the surface of the ground. The brick part of the pier is 48.5 inches high, capped by a block of marble 36 inches in diameter and 12 inches thick, upon which the instrument stands.

The site of the altazimuth instrument was agreed upon after an exhaustive discussion by the whole astronomical staff of the Observa-

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tory, and was marked on the ground on August 10, 1897, by the superintendent, the astronomical director, and Assistant Astronomer Hill. The pier and the foundation for the building were constructed in August and September, 1897; the building was erected in the end of November, and the instrument was mounted in December, but on account of some small changes which proved necessary it was not brought into use until February, 1898. The first observations with it, used as a zenith telescope and as a vertical circle, were made, respectively, on February 8 and February 24, and by June 30, 1898, 293 zenith telescope observations and 71 vertical circle observations were accumulated, a further account of which is given in connection with the prime vertical transit instrument. It was soon found that in observing stars in the daytime the revolving dome sometimes came into such a position as to expose the instrument to the sun's rays, and to remedy this, and at the same time afford a means of protecting the instrument from the wind when necessary, movable curtains were fitted inside the slit during the latter part of May, 1898.

When the 6-inch transit circle and the 5-inch altazimuth instrument were contracted for, this Observatory was severely criticised, first, for intrusting them to an American firm, and, second, for venturing to make an altazimuth at all. I think we have now had sufficient experience with both instruments to show that the workmanship will compare favorably with anything ever turned out of a European workshop, and that the altazimuth instrument used as a vertical circle will give more accurate declinations than can be obtained with a transit circle.

THE PRIME VERTICAL TRANSIT INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

This instrument has been used in connection with the small meridian instrument, Stackpole & Bro., No. 1502, up to February 4, 1898, and since then in connection with the new altazimuth instrument, for determining variations of latitude and the constants of aberration and nutation, precisely as described in former reports.

The number of observations obtained during the twelve months ending June, 30, 1898, was as follows: With the prime vertical transit instrument, μ Andromedæ, 16; α Canum Venaticorum, 7; θ Aurigæ, 31; α Lyræ, 102; 40 Cygni, 4. With the Stackpole meridian instrument used as a zenith telescope, α Lyræ, 66. With the new altazimuth instrument used as a zenith telescope, α Canum Venaticorum, 21; γ Bootis, 24; α Lyræ, 46. Total, 317 observations. This is 12 per cent less than the number of observations obtained during the fiscal year 1896–97, but the difference is accounted for by the unusual prevalence of cloudy weather in the spring of 1898.

In addition to the above observations of close zenith stars, it was intended to make another series upon certain bright stars of somewhat greater zenith distance, employing for that purpose the altazimuth instrument used as a vertical circle, but upon trial it was found that the zenith points given respectively by the upper and lower alidade levels of the altazimuth differed systematically, and the cause of this discordance was not discovered until the end of July, 1898. During the continuance of the uncertainty respecting the indications of the alidade levels the instrument could best be employed as a zenith telescope, and accordingly 202 observations of 39 pairs of stars were made with it between April 2 and June 30, 1898.

All observations with the prime vertical transit instrument are com-

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pletely reduced, and those made prior to January 1, 1898, are copied on sheets for the printer. The zenith telescope observations made with the Stackpole meridian instrument are also all reduced, but those made with the altazimuth instrument are only provisionally reduced because of a doubt as to the exact value of a revolution of the micrometer screw. That can be best determined from observations of certain stars in the Pleiades, but soon after the instrument was mounted they passed into the daylight. When they come into a suitable position this fall a careful series of observations will be made upon them.

All our observations for variation of latitude, both with the prime vertical transit instrument and with the zenith telescope, up to October 17, 1897, have been sent to the Centralbureau der Internationalen Erdmessung, and were used by Dr. Th. Albrecht in his "Bericht über den Stand der Erforschung der Breitenvariation im December, 1897."

Prior to 1897.55 there were made here 852 prime vertical observations and 370 zenith telescope observations, all of which have been reduced with the star-places given in the "Catalogue of fundamental stars for the epochs 1875 and 1900, reduced to an absolute system," prepared under the direction of Prof. Simon Newcomb, and from them I find for the latitude of the center of the clock room of the Naval Observatory + 38° 55′ 13.97″.

THE TRANSIT CIRCLE STAR CATALOGUE.

[Prof. JOHN R. EASTMAN, U. S. N., in charge.]

In the preparation of this catalogue Professor Eastman has been assisted throughout the year by Mr. F. H. Parsons, temporarily employed for the purpose, and by Computer William M. Brown, who has devoted about two-thirds of his time to the work. The comparisons of the transit circle star-places with those given by other authorities, including the new "Catalogue of fundamental stars for the epochs 1875 and 1900, reduced to an absolute system," by Professor Newcomb, have been continued during the last twelve months, with the result of weeding out some errors, and the explanatory text and discussions pertaining to the annual results have been completed. The manuscript was put into the hands of the printer about the middle of February, and the composition and stereotyping will certainly be completed before August 1, 1898. The work is entitled "The second Washington catalogue of stars, together with the annual results upon which it is based; the whole derived from observations made at the United States Naval Observatory with the 8.5-inch transit circle during the years 1866 to 1891 and reduced to the epoch 1875.0," and will form a quarto volume of 350 pages. It contains the places of 5,151 stars, based upon 72,914 observations, and to obtain the utmost possible security against typographical errors the last proof reading was made upon impressions taken from the stereotype plates.

MISCELLANEOUS MATTERS.

Mr. Charles T. Fellows, who had been attached to the Observatory as photographer since August 11, 1893, died on April 8, 1898, after being in bad health for some months. He knew his business thoroughly, and discharged his duties so pleasantly and efficiently that I fear it will be difficult to find another man who will be in all respects as satisfactory.

During the year the following named articles have been added to the permanent equipment of the astronomical department: July 30, 1897,

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one Weston's standard portable alternating and direct current voltmeter No. 1647, one Weston's direct reading voltmeter No. 6719, and one Weston's direct reading ammeter No. 3383. On the same date there was also received a new cover for the heliostat and objective of the 40-foot photoheliograph; November 30, one polished mahogany box, with lock and key, in which are packed the micrometer and eyepieces belonging to the 9.6-inch equatorial telescope, and two polished mahogany boxes in which are packed various pieces of apparatus belonging to the 9.14-inch transit circle.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics, U. S. N., Astronomical Director.

The SUPERINTENDENT U. S. NAVAL OBSERVATORY,
Georgetown Heights, D. C.

DEPARTMENT OF THE NAUTICAL ALMANAC.

Upon the detachment of Prof. William W. Hendrickson, U. S. N., this department was, upon the recommendation of the Superintendent of the Observatory, placed under the charge of the astronomical director.

It was believed that, in view of the relations of these two departments to each other, better results could be obtained if both were under the same general control. As far as can be inferred from one year's experience, this expectation has been realized.

The report of the Director of the Nautical Almanac is given below:

NAUTICAL ALMANAC OFFICE,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., July 1, 1898.

SIR: I have the honor to submit the following report respecting the operations of the Nautical Almanac Office for the fiscal year ending June 30, 1898:

PRINTING.

The books printed during the year were received from the Government Printer on the following-named dates: The American Ephemeris for 1900, first edition, December 6, 1897; the American Nautical Almanac for 1898, third edition, April 4, 1898, fourth edition, May 4, 1898; the American Nautical Almanac for 1899, second edition, November 2 to 29, 1897; the American Nautical Almanac for 1900, second edition, November 22, 1897; the American Nautical Almanac for 1901, first edition, June 30, 1898; the Pacific Coaster's Nautical Almanac for 1898, first edition, September 24 to October 29, 1897, second edition, March 24, 1898; Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, volume 8, part 1, The Precessional Constant, July 30 to August 17, 1897.

DISTRIBUTION OF PUBLICATIONS.

During the fiscal year ending June 30, 1898, the sale and distribution of publications were as follows:

Title.	Sold.	Distributed.	Bureau of Equipment.	Public service.	Total.
American Ephemeris	545	309	179	631	1,664
American Nautical Almanac	2,565	.....	40	337	2,942
Pacific Coaster's Almanac	1,503	.....	.....	52	1,555
Astronomical Papers	56	131	.....	.....	187

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The proceeds of the above sales amounted to $1,368.48, and, in compliance with law, that money has been deposited to the credit of the Treasurer of the United States, on account of public printing and binding.

NEW TABLES OF THE PLANETS.

Upon the retirement of Prof. Simon Newcomb, U. S. N., in March, 1897, he was appointed to supervise the completion of his tables of Mars, Uranus, and Neptune, and since then he has constantly had the services of two of the best assistants in the office, and whenever he desired additional computers they have been furnished him so far as they could be spared from other duties. The manuscript of the tables of Mars was sent to the printer on January 18, 1898, and the composition and stereotyping were completed in the end of May, but on account of the extra work entailed upon the Government Printing Office by the war with Spain the printing is not yet commenced. The tables of Uranus and Neptune are so far advanced that Professor Newcomb hopes the manuscript will be ready for the printer some time in October.

CATALOGUE OF STANDARD STAR PLACES.

"The Catalogue of Fundamental Stars for the Epochs 1875 and 1900, reduced to an absolute system," which was undertaken by Professor Newcomb under the auspices of the Paris conference of May, 1896, will form a quarto volume of about 290 pages, and will soon be ready for issue. The manuscript was sent to the printer on June 17, 1898, and 170 pages were in type at the end of the fiscal year.

CONSTANTS OF PRECESSION, ABERRATION, AND NUTATION.

The values of the constants of aberration and nutation adopted at the Paris conference of May, 1896, together with an unique value of the constant of precession, were introduced by my predecessor into the American Ephemeris for 1900, and the apparent places of the fixed stars were calculated with these constants, but this procedure met with so much opposition among prominent American astronomers that it has been thought best to give in the Ephemeris for 1901 sufficient data to enable either the constants of Struve and Peters or those of the Paris conference to be used with equal facility, and thus each astronomer is left free to choose for himself which he will employ. The retention of the Struve-Peters constants in the Ephemeris for 1901 has necessitated the computation of a new set of star tables, the old ones having run out in 1900, but, notwithstanding the extra work thus thrown upon the Office, it is believed that the Ephemeris for 1901 will be issued at a relatively earlier date than was that for 1900.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics, U. S. N.,
Director Nautical Almanac.

The SUPERINTENDENT U. S. NAVAL OBSERVATORY,
Georgetown Heights, D. C.

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Department of Nautical Instruments.

The following report of Prof. Stimson J. Brown, United States Navy, gives the history of the personnel and a statement of work in this department.

The recommendation that the system by which chronometers and sextants are purchased be extended to other instruments is approved, but it is suggested that no steps be taken in this direction until the extraordinary demands due to the existing war cease, when plans for such extension can be fully and carefully considered.

SIR: I have the honor to submit the following report for the fiscal year ending June 30, 1898, of the department of nautical instruments and of the general storekeeper's department combined, as the work of the two has been generally merged together on account of the lack of sufficient force of officers to carry them on separately.

Lieut. T. M. Brumby, United States Navy, was in charge of the department of nautical instruments from October 1 to October 30, 1898, when he was detached and ordered to sea. I have had general supervision of this department, assisted in the examination of instruments by Computer E. A. Boeger, who has performed nearly all the work of inspection.

The purchase of sextants by award of contract to lowest bidder was so far modified as to invite instrument makers to submit sextants made in accordance with careful specifications, the contract to be awarded at a stated price to the maker whose instruments showed the highest accuracy and perfection of work. Four firms submitted a sample sextant of the two classes called for (a high-grade sextant at $100 and a surveying sextant at $90), with the exception of Warner & Swasey, who submitted only the sample high-grade sextant. As a result of the competition, the contract for the high-grade sextant was awarded to Warner & Swasey, of Cleveland, Ohio, and for the surveying sextant to F. E. Brandis, Sons & Co., of Brooklyn, N. Y.

I think this principle could be extended, to the advantage of the Department, to the purchase of nearly all the nautical instruments for the use of the Navy.

The number of instruments purchased and inspected will be given in a table under the general storekeeper's report.

The duties of general storekeeper were performed by Commander Walton Goodwin, United States Navy, until his detachment for sea duty, May 18, 1898. Since that date these duties have been performed by me in addition to my regular duties with the 26-inch telescope.

The following table shows the number of instruments inspected and purchased, the number purchased abroad, and the number issued to vessels of the Navy and to other sources. This does not include the chronometers, comparing watches, and stop watches, which are given in the report of department of time service and chronometers, as also several miscellaneous instruments and apparatus used in connection with the ships' compasses.

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Nautical instruments inspected, purchased, and issued.

Instrument.	Purchased after inspection.	Purchased abroad.	Issued.
High-grade sextants	7	.....	36
Ordinary sextants	7	a 44	13
Surveying sextants	32	.....	33
Octants	42	25	100
Binocular glasses	320	.....	424
Spyglasses:			
Quartermaster	202	.....	135
Officer of the deck	125	.....	183
Three-arm protractors	20	.....	10
Thermometers	100	.....	100
Aneroid barometers	101	.....	89
Cases captains' reading glasses	25	.....	15
Navigators' dividers	75	.....	75
Psychrometers	45	.....	26
Deck clocks	100	.....	72
Boat clocks	50	.....	24
Clinometers	20	.....	24
Radiimeters	6	.....	6
Stadimeters (Fiske)	.....	.....	2
Telemeters (Lowry)	10	.....	3
Parallel rulers (Sigsbee)	35	.....	31
Parallel rulers, 15, 18, and 24 inch	125	.....	145
Cases drawing instruments	25	.....	15
Standard steel tapes	25	.....	10
Theodolites	.....	.....	3
Surveyors' levels	.....	.....	1
Sets magnetic instruments	.....	.....	6
T-squares	25	.....	20
Artificial horizons	.....	.....	7

a Of the 44 ordinary sextants purchased abroad by the naval attaché at London, 19 were kept at the New York Navy-Yard for issue.

The aggregate value of the instruments purchased was $45,781.98. There were made 345 shipments of instruments, the invoice value of which was $56,467.40. These amounts are largely in excess of the general experience of the Observatory, and are due to the sudden demands incident to the naval operations against Spain. The extent of the demand may be best shown by a comparison with the shipments for the last three previous years. These were—

	Shipments.	Value (approximate).
1895	92	$17,443
1896	178	29,117
1897	186	24,088
1898	295	41,853

The last were made in the period from March 1, 1898, to May 16, 1898.

To meet this increased demand all the available nautical instruments in this country were purchased and additional supplies purchased from abroad. In no case was there any delay in supplying demands, although the Observatory force was largely reduced by the detachment of officers for service at sea.

Respectfully submitted.

S. J. BROWN,
Professor Mathematics, U. S. N.,
Head of Department of Nautical Instruments,
and Acting General Storekeeper.

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DEPARTMENT OF CHRONOMETERS AND TIME SERVICE.

The heads of this department during the year have been as follows: Lieut. Charles E. Fox, United States Navy, from July 1 to October 20, 1897; Lieut. A. N. Mayer, United States Navy, from October 20, 1897, to June 18, 1898, and Prof. H. M. Paul, United States Navy, from June 18 to the end of the fiscal year.

Professor Paul was on duty in the department during the whole year, and Computer M. E. Porter from July 1 to October 11, 1897. Professor Paul makes the following report:

CHRONOMETERS.

SIR: The opening of the war with Spain interfered with the regular annual trial of repaired chronometers and of those submitted for purchase. The trial in the temperature room was begun on January 10 with 26 repaired chronometers (20 M. T. standards, 2 M. T. B. C., 2 Sid. B. C., and 2 Thermometric) and 13 new ones. These, together with the ones still unissued from the previous year's trial, would ordinarily have sufficed for issue during the year 1898–9; but the demand for chronometers for the "mosquito fleet" and other newly acquired vessels quickly exhausted the supply on hand, encroached upon the trial (some being issued before the temperature trial was completed), and, before the end of the twelve weeks' subsequent trial in the chronometer room, all the 20 repaired standards and the 13 new ones were issued and afloat, the new ones having all been purchased without completing their regular trial.

This is the reason for the omission from this report of the usual tabular pages of rates and resulting trial numbers. For the same reason the above-mentioned chronometers, and the much larger number subsequently purchased which are referred to below, have all been issued to vessels without the usual temperature coefficients and rate curves.

The demands of the rapidly growing auxiliary navy required emergency purchases of chronometers, many of them being issued to vessels after a trial of only two or three weeks at the Observatory. The supply of new chronometers in this country was soon exhausted and 25 were ordered by cable from London. Of these latter, 10 were issued direct from the New York Navy-Yard, the other 15 coming to the Observatory. These 15 proved fairly satisfactory, although nearly all that remained here many weeks showed a considerable acceleration of rate, as most new chronometers do.

Later on, a considerable number of nearly new chronometers were purchased of makers in this country after a trial of a few weeks at the Observatory, and the supply of these in American makers' hands, together with the new ones now in process of manufacture, will probably suffice for all future demands without further purchases abroad.

Eleven chronometers have been purchased with the newly acquired vessels, and 7 of the best of these have been left on board as standards, and the others cleaned, repaired, and issued as hacks.

Four standards have been condemned to be used as hacks, and 3 second-hand ones purchased for similar use, the supply of hacks having run out and being still short.

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The whole number of chronometers received and issued during the year is most concisely and conveniently shown in the following tabular statement:

	Receipts.								Issues.			
	By purchase.				Turned in from—							
	New.	Nearly new.	With ships.	For hacks.	Ships.	Shore stations.	Makers, repaired.	Condemned to be hacks.	To ships.	To shore stations.	To makers for repairs.	Condemned to be hacks.
M. T. standards	34	46	7	.....	45	.....	39	.....	131	1	40	4
M. T. hacks	.....	.....	4	3	9	1	16	4	24	.....	17	.....
M. T. bk circ	.....	.....	.....	.....	.....	1	2	.....	.....	.....	1	.....
Sid. bk circ	.....	.....	.....	.....	.....	3	2	.....	1	3	4	.....
Sid. standards	.....	.....	.....	.....	.....	.....	1	.....	.....	1	1	.....
Thermometric	.....	.....	.....	.....	.....	.....	2	.....	.....	2	.....	.....

The above table includes the chronometers received and issued at Mare Island, Cal., for the Pacific and Asiatic squadrons, in addition to the same for the Observatory.

The large numbers of 94 chronometers purchased and 156 issued to ships (most of them in the last four months) are striking illustrations of the war demands upon this branch of the service.

The present location of all the chronometers belonging to the Navy is shown in the following table:

Description.	Location.									Total.
	Outside Observatory.			At Observatory.						
	In service afloat.	At Mare Island.	At other shore stations.	Ready for issue.	In use at Observatory.	Undergoing repairs.	Held for repairs.	Held for survey.	Held for museum.	
M. T. standards	238	39	11	19	.....	.....	.....	.....	3	310
M. T. hacks	66	11	21	.....	3	2	.....	17	18	138
M. T. bk circ	.....	1	4	2	.....	.....	.....	.....	.....	7
Sid. bk circ	1	2	1	.....	4	3	.....	.....	.....	11
Sid. standards	.....	1	.....	.....	1	.....	.....	.....	.....	2
Sid. hacks	.....	.....	.....	.....	3	.....	.....	.....	.....	3
Thermometric	.....	.....	.....	.....	2	.....	2	.....	.....	4
Pocket	.....	.....	1	.....	.....	3	2	.....	.....	6
Total	305	54	38	21	13	8	4	17	21	481

The chronometers at Mare Island are for issue to the Pacific and Asiatic squadrons and to the shore stations of the Pacific coast. The 17 chronometers held for survey are nearly all worn-out hacks which should be condemned. Twenty-one chronometers are held for display in an Observatory museum whenever space is available for it. They are all of some historical interest, mostly connected with arctic exploration. Very few of them are serviceable, but they are reserved from condemnation on account of their history.

WATCHES.

During the year 90 comparing watches and 32 stop watches have been purchased, and 87 comparing watches and 34 stop watches issued

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to ships. There remain on hand ready for issue 22 comparing watches and 16 stop watches.

THERMOMETERS.

There have been issued to ships during the year 19 maximum and minimum thermometers, and 7 are on hand for issue. None have been purchased during the year.

TIME SERVICE.

The one sidereal and two mean-time standard clocks, as well as the two transmitting clocks for noon signals, have all performed fairly well, and the noon signals have been sent out every day in the year except Sundays. Recently the signals have been sent occasionally on Sundays for the benefit of the warships and transports at Key West. The reports from the branch hydrographic offices show a fair degree of regularity in the dropping of the time balls under their control.

Computer M. E. Porter has rendered very efficient service in all branches of the work in this department.

Very respectfully, H. M. PAUL,
Professor of Mathematics, United States Navy,
Head of Department of Chronometers and Time Service.

DEPARTMENT OF MAGNETISM AND METEOROLOGY.

In the last annual report of the Observatory attention was called to the disturbances of the magnetic instruments caused by the proximity of electric railways. The same conditions exist now and, owing to extension of electric-railway systems, to a greater degree. Unless legislation can be secured preventing the use of circuits which permit the escape of electricity into the ground, it is feared that the usefulness of the magnetic plant of this Observatory will be entirely destroyed.

It is of interest to note that other magnetic observatories have had the same experience. Those at Toronto, Greenwich, Lyons, and Clermont-Ferrand have been rendered practically useless by electric railways constructed in their vicinity, and the observatory at Saint-Maur, France, is threatened with a like misfortune.

LIBRARY.

Assistant Librarian William D. Horigan has direct charge of the library, under the general supervision of the library committee:

	Volumes.	Pamphlets.	Total.
Contents of the library July 1, 1897	16,036	3,411	19,447
Accessions	564	156	720
Contents July 1, 1898	16,600	3,567	20,167

Of the accessions, 341 were received as exchanges and 379 were purchased.

The report of the Superintendent for 1897 was distributed.

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BUILDINGS AND GROUNDS.

All of the buildings connected with the Observatory are in good condition.

A small building adapted to the use of an equatorially mounted instrument has been erected for the recently purchased alt-azimuth instrument.

The west transit-circle house has been completed in the manner described in the report of the Astronomical Director, for the mounting of the new 6-inch transit instrument.

Owing to the reduction in the amount appropriated for the purpose, no very marked progress has been made in new improvements to grounds and roads, but they have been kept in satisfactory order.

Very respectfully,

R. L. PHYTHIAN,
Commodore, U. S. N., Retired,
Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

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REPORT

OF THE

SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1900.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1900.

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REPORT

OF THE

SUPERINTENDENT OF THE NAVAL OBSERVATORY.

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., October 16, 1900.

SIR: I have the honor to submit the annual report of the operations of the United States Naval Observatory for the fiscal year ending June 30, 1900.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

The work of the year in this department may be summarized as follows:

Prof. William Harkness, who retired from active service on December 15, 1899, was succeeded in the astronomical directorship by Prof. Stimson J. Brown, the senior professor of mathematics on duty at the Observatory. Professor Brown's first duty was as member of a board of examiners, to fill the vacancy caused by the retirement of Professor Harkness by the selection of a suitable candidate for appointment as professor of mathematics in the Navy. The labors of this board, of which Prof. William Hendrickson, U. S. N., was senior member, resulted in the selection and appointment of Prof. W. S. Eichelberger. In this connection it is pertinent to observe that the present condition of the astronomical staff of the Observatory is highly satisfactory, and gives promise for the future. The vacancies, caused by the rapid successive retirement of the older professors, have all been filled by young men of marked ability, and the Observatory has followed its traditional policy in this respect, and has every reason to anticipate a renewed activity and a period of harmony, industry, and usefulness.

All the astronomical instruments of the Observatory have been steadily and continuously in use during the year on every clear night and day.

The XXVI-inch equatorial telescope has been employed on the observation of difficult double stars, the satellites of the planets and the measurement of their disks, and on other objects suitable to an instrument of its power. This instrument was in charge of Professor Brown, assisted by Prof. T. J. J. See until December 15, and has since been in charge of Professor See.

In the month of October, during the hazy weather common at that season, the images of celestial bodies were marked by great steadiness in the field of view, unusual at other times. Owing to this favorable condition Professor See noticed on several occasions faint markings on the disk of Neptune, similar to the equatorial belts of the planets Jupiter and Saturn. The fine definition at this time was ascribed to

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the selective absorption of the haze caused by the smoke of forest fires, and an attempt has been made by Professor See and Mr. George H. Peters, the photographer, to reproduce artificially the same conditions by the use of a color screen. The idea of this application to the telescope was not wholly new, although it was believed to be so at the time. It is too early to speak definitely on the result of these experiments, except to say that the general effect of the use of a screen composed of two thin sheets of plate glass, the space between them being filled with a solution of chloride of copper and picric acid, or a solution of bichromate or chromate of potash, seems to have the effect of absorbing the blue rays and removing the halo which surrounds bright objects in the field of a large achromatic telescope, and the image appears somewhat steadied. The color screen is now in use in observations of the diameters of the planets and measurable satellites.

During the year the double floor, which was appropriated for last year, designed to obviate the difficulty experienced from currents of warm air rising from the basement, has been finished, and answers every expectation, giving highly satisfactory results.

The IX-inch transit circle was undergoing its periodical repairs and general overhauling from the beginning of the fiscal year until January 20, 1900, during which time the routine work of the sun, moon, and planets was carried on with the new VI-inch steel transit circle. Since the resumption of the regular work on the IX-inch circle, Professor Skinner has had charge of the zone observations and Professor Eichelberger of the routine sun, moon, and planet work, while the VI-inch circle, in charge of Professor Updegraff, has been under strict investigation, with a view to determining the causes of several faults made apparent by the routine work and probably unavoidable in a new instrument.

In the meridian work a total of 1,114 observations of zone stars and a total of 3,105 observations in the sun, moon, and planet work have been made during the year.

The XII-inch equatorial has been used for observations of comets, asteroids, and other miscellaneous objects, and will soon undergo extensive repairs and alterations.

Assistant Astronomer George A. Hill has devoted the prime vertical transit to observations of α Lyræ and a small list of suitable stars in the investigation of the variation of the latitude and the constants of nutation and aberration, and the same observer has used the new V-inch steel alt-azimuth instrument principally as a zenith telescope for observations for latitude by Talcott's method and for the declinations of stars of the American Ephemeris.

The 40-foot photoheliograph has been used in making daily photographs of the sun whenever the weather permitted, except after April 2, during preparations for the observations of the total eclipse of the sun on May 28.

By an appropriation of $5,000 the Observatory was able to undertake observations of the total eclipse of the sun on the date above mentioned. Two parties were sent into the field, and attention is respectfully invited to the detailed report of the astronomical director on this subject, and also to the recommendation for an appropriation to cover the expenses of a similar expedition this year, in the eclipse of May 17, 1901, which is approved and indorsed.

Preparations are now in progress for installing at the Observatory a new standard clock which shall be entirely freed from the influences

of changes of temperature, and the recommendations of the astronomical director on this subject are approved.

The work of bringing up the publications of observations to date, which has been in arrears for several years, is being vigorously pushed, and the issue of the first volume of the new series of Washington observations, commencing with the first year of the observatory's work on the present site, will soon occur, to be followed by the succeeding volumes in rapid succession. The delay in the publication of its work has been made a reproach to the Observatory, although the causes of this delay have been reasonable and unavoidable, but the most earnest and determined effort is being made to relieve the observatory of a condition which has been used to its disadvantage in outside criticism.

The report of the astronomical director is herewith transmitted in full.

The department of magnetism has been discontinued, as noted in the last report of the superintendent. The buildings and instruments are, however, maintained in perfect order under the charge of Assistant Astronomer Theo. I. King. The Georgetown and Tennallytown Electric Railway has already installed a return wire which, it is reasonable to suppose, it intends sooner or later to use. When this road ceases to ground its powerful working currents, an attempt will be made to resume magnetic observations at the Observatory. The result is dubious. Moreover, the Observatory is to a lesser extent within the influence of the Chevy Chase road, which would continue to affect observations.

The following changes in the personnel of the Observatory have occurred during the year:

Prof. William Harkness was succeeded as astronomical director by Prof. Stimson J. Brown, the senior professor of mathematics, in December, 1899.

Prof. Milton Updegraff reported for duty July 15, 1899; was assigned to duty in the astronomical department.

Prof. W. S. Eichelberger, a former computer, was appointed after a competitive examination; he reported for duty February 17, 1900, and was assigned to the astronomical department.

Computer J. C. Hammond was transferred from the Nautical Almanac Office to the Observatory February 20, 1900, and was assigned to the astronomical department.

Department of Chronometers and Time Service.

I invite the attention of the Bureau to the recommendation of the head of the department of chronometers and time service, and of the department of nautical instruments and general storekeeper, in which I concur. These two departments should be under separate heads. The estimates for the next year show one stenographer and typewriter submitted for general clerical service at the Observatory. Should this estimate be granted, the clerk who now assists in the work of the general storekeeper could give more time to that duty; but the estimate of the head of the department is not excessive. I believe that the Observatory is the only station at which the general storekeeper system prevails which is allowed no assistance whatever—clerical or otherwise. As the work of this department must and should be kept up, as it forms an increasingly important part of the general functions and usefulness of the Observatory as a naval establishment,

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a computer from the astronomical department has been assigned to assist in the time service and the clerk of the Observatory to assist in the accounts of the general storekeeper. This expedient can be regarded only as temporary. When the public service require work to be done, it is not unreasonable on the part of those charged with its execution to request the means of doing it.

An objection to the present arrangement exists in the danger that the continuity of work in the general storekeeper's department may at any time be seriously interrupted by the sudden detachment of the Navy officer in charge. There should be a permanent force of assistants in this office. It has occurred to me to suggest that the Department might reasonably consider the assignment to duty at the Observatory, under the provisions of the naval act of this year, of one or more retired line officers of suitable age and tastes for the departments of chronometers and time service, and of nautical instruments, and as subordinates to the active head of those departments.

Grounds and Roads.

Since my last report the offer which I therein noted to purchase a certain tract of the Observatory land lying outside the proposed Observatory circle has been withdrawn, owing to the doubt as to the projected grade of Massachusetts avenue extended. The settlement of this question seriously threatened the interests of the Observatory property. Acting under the instructions of the Department, I have, from time to time, conferred with the District Commissioners, with the result that the understanding has been reached that no steps would be taken detrimental to the Observatory without my being informed. I believe this question will be settled without prejudice to the Observatory's interests, and I renew my recommendation that no land lying outside the proposed Observatory circle be sold, except possibly the tract which was the subject of negotiation last year. This would not preclude the acquisition, by purchase, of lands lying within the proposed circle should the extension of roads, etc., in the neighborhood make it desirable to add them to the Observatory domain.

Board of Visitors.

As noted in my last report, and for the first time in its history, a board of visitors was appointed which visited the Observatory in June and again in September, remaining a few days at each visit. As the report of the board, which was not made available to the Observatory until long after its substance had appeared in the public prints, was in the nature of an attack on the Observatory, I trust that it will not be out of place, in the report of the Superintendent, to touch upon its salient features.

The board was unfortunate in having the support of several zealous newspaper writers, by whom it has been made to appear, and I think that it is generally believed in the scientific world and by that part of the public which takes an interest in scientific affairs, that the presence of the board was in the nature of a visitation distasteful to the Observatory and inflicted against its will. As the Observatory has thus been made to appear in an odious light, I take the liberty of reminding the Bureau that not only the original conception of the board of visitors was a suggestion of the Superintendent, but the selection of the three astronomical members was concurred in by him because they were

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already the members of a self-constituted committee to conduct a gratuitous investigation of the Observatory, and known to be inspired by a hostility to its organization. It was hoped that by placing them in a position of official responsibility an impartial judgment could be obtained.

A criticism of the report may be very briefly summarized. The board made no examination or inspection of the Observatory except in the most casual way. To quote its own language, "Owing to the lack of printed material representing the recent work of the Naval Observatory, the board of visitors finds it practically impossible to form a satisfactory opinion of that work without devoting to the task an inadmissible amount of time and labor." Nevertheless, and without such an opinion, the board did not hesitate to recommend the most sweeping changes in the present organization, and it is noticeable that the report of the board deals exclusively with the question of reorganization, while that question had not been officially presented to it at all. As a guide to the board the following letter of instructions was addressed to it by the Department:

NAVY DEPARTMENT,
Washington, June 28, 1899.

SIR: I have the honor to inclose you herewith a memorandum making certain suggestions which the Department wishes the board, of which you are the chairman, to have in mind in making an examination of the Naval Observatory. This memorandum is not intended to finally limit the investigations of the board, but to convey certain suggestions in regard to which the Department desires to be informed, and which, it is believed, may assist the board in its work.

JOHN D. LONG, *Secretary.*

Hon. WM. E. CHANDLER,
Chairman Board of Visitors, Naval Observatory, Washington, D. C.

MEMORANDUM RESPECTING THE FUNCTIONS OF THE PROPOSED BOARD OF VISITORS TO THE NAVAL OBSERVATORY.

The board of visitors is authorized to examine the equipment and working of all parts of the Naval Observatory and to make any suggestions which may seem desirable for improving the scope and efficiency thereof, but in so doing the following facts should be borne in mind:

1. Perhaps the most important astronomical duty of the Government is the publication of a nautical almanac, and as that is intended not only for the use of navigators, but also for the guidance of astronomers in the most delicate investigations known to their science, it should evidently be kept up to the highest attainable pitch of accuracy. To that end a continuous series of meridian observations upon the sun, moon, planets, and stars is absolutely necessary, and as such observations upon the sun, moon, and major planets are practically confined to the Government observatories at Greenwich, Paris, and Washington, the necessity for making them the primary work of the Naval Observatory hardly seems open to discussion. The importance of observing satellites in order to determine the masses of their primaries is evident, and in that connection the question of providing the Naval Observatory with a large heliometer may well be considered.

2. As a secondary object, the Naval Observatory has always found it possible to make many observations of asteroids, comets, and double stars, and it has recently obtained spectroscopic apparatus for investigating the motions of stars in the line of sight; but the board might well consider how far such secondary work should be extended, and whether or not it is desirable to obtain a 13-inch photographic telescope for the purpose of mapping more or less extended portions of the heavens.

3. The needs of the Navy necessitate the testing of a large quantity of instruments to be used at sea, among which chronometers occupy a very prominent position. The processes employed have gradually grown up at the Naval Observatory, and as there is very little precedent for most of them, the opinion of the board on their scope and thoroughness would be valuable.

4. The operations of the electric street railways in the vicinity of the Naval Observatory have interfered so much with the continuous magnetic observations

formerly made there as to cause their suspension. In view of the small number of magnetic observatories in North America, this seems so serious a loss to science that the board might well consider whether or not anything can be done to remedy it.

5. In the opinion of those responsible for the management of the Naval Observatory, its most serious defect at the present moment is the backwardness of its publications, but that has arisen through circumstances which were hardly avoidable, and which are not likely to recur in the future. The equipping of a new observatory, and the observation of the zone of stars lying between 13° 50′ and 18° 10′ of south declination for the international catalogue of the German Astronomical Society, while at the same time the series of meridian observations upon the sun, moon, and planets was continued as usual, rendered it impossible for the limited staff to keep the reductions up to date. If work is continued on the present lines, it is believed that these arrears can be brought up in about three years, and after that it should be possible to have each annual volume appear within about eighteen months after the date of the last observation it contains. As the removal to the new Naval Observatory may naturally be regarded as marking the beginning of a new series of publications, the board might well consider whether or not any changes are desirable in the forms adopted for printing the observations.

Not one of the subjects proposed in the above memorandum received the attention of the board or was even mentioned by it. The whole report is taken up with the proposed reorganization, a subject which it had not been asked to consider at all, and for which it could only find a general authorization in the concluding paragraph of the Department's letter.

Notwithstanding that the board had no time to form an opinion as to the condition of work at the Observatory, the conclusion upon which it bases a recommendation for a revolutionary change of organization is found in the charge that the output, in published results, is not commensurate with an extravagant annual outlay. In other words, the board lays particular stress upon the delay in the publication of the annual volume, and bases its whole finding upon that fact.

The board makes a comparison between the Naval Observatory and the observatories at Greenwich and Harvard, selecting the former because it is supposed to cover nearly the same field, and the latter because it also undertakes large pieces of routine work which are beyond the reach of smaller observatories, because the resources of Harvard approach more nearly than do any other those of the Naval Observatory, and because all the details of the Harvard Observatory were readily available, its director being a member of the board.

I ask the attention of the Bureau to the following table, which gives an exact comparison of the three observatories chosen by the board, and which, almost without elucidation, confutes the sole and only charge made by the board against the efficiency of the Observatory upon which charge the only recommendation of the board rests.

Comparison of number and cost of scientific personnel of Greenwich, Harvard, and Naval observatories, previous to July 1, 1900:

GREENWICH OBSERVATORY.

Scientific personnel.	Number.	Average.	Total.
Director	1	$5,000	$5,000
Chief assistants	2	2,550	5,100
First-class assistants	4	2,000	8,000
Second-class assistants	4	1,200	4,800
Magnetic superintendent	1	1,700	1,700
Assistant magnetic superintendent	1	1,000	1,000
Computers	23	325	7,475
Total	36	.....	33,075

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HARVARD COLLEGE OBSERVATORY.

Scientific personnel.	Number.	Average.	Total.
Director	1	$5,000	$5,000
Astronomers	6	2,000	12,000
Assistant astronomers	13	900	11,700
Computers	18	600	10,800
Total	38	.....	39,500

UNITED STATES NAVAL OBSERVATORY.

Astronomical director	1	$3,500	$3,500
Other professors of mathematics	4	2,700	10,800
Assistant astronomers	3	1,900	5,600
Computers	6	1,200	7,200
Photographer	1	1,200	1,200
Total	15	.....	28,300

A comparison of the figures in this table shows that the number of astronomers employed at the Naval Observatory is 5, at Greenwich 3, at Harvard 7. The Naval Observatory has the advantage of Greenwich and decidedly the disadvantage of Harvard. In the matter of assistants, however, the case is different. The total of assistants at Greenwich is 8, at Harvard 13, and at the Observatory 3; while the computers stand, Greenwich 23, Harvard 18, Naval Observatory 6.

In the years 1891 to 1893 the Observatory was removed from the site which it had occupied for nearly fifty years, to its present situation. The delays in building, the labor of dismounting and remounting the instruments, the repairs and alterations of the same and their subsequent installation, the removal of the records and Observatory property, and generally the labor involved in settling in the new place, absorbed the entire time of the whole very limited working force of the Observatory for several years. The publication of results, from this cause and from this cause alone, fell into arrears. The force of the astronomical staff, sufficient for current work in settled times, was totally inadequate to bring up back work when the work had fallen behind. It was simply a physical impossibility to keep up the publications, and to make the current observations and do the necessary work of removal at the same time. This and this alone is the cause of the delay in printing, and when the number of assistants and computers at the Observatory is contrasted with the numbers at Greenwich, and especially at Harvard, the delay is reasonable on its face. These facts were represented to the board, but are nowhere given in its report. The board, on the contrary, evaded and concealed them. It might have reasonably been shown that during the whole of this transition period current work was practically uninterrupted, and that the number of observations made at the old and new observatories kept pace with those made at Greenwich. But "owing to the lack of printed material the board found it impossible to form a satisfactory opinion upon that work, without devoting to the task an inadmissible amount of time and labor." The facts were laid before the board and ignored by it. They would have shown to the credit of the Observatory.

It is needless to say that the figures in the above table are not given by the board in its comparison of the three observatories named as they are given here. The board had to make a case against the Observatory, and the charge of extravagance of outlay in proportion to the output of results had to be substantiated. Accordingly the whole staff

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of the Observatory, scientific and lay, is contrasted with that at Harvard, and the numbers are brought to an equality by adding in the artisans and laborers employed about the buildings and grounds, Harvard having practically none. By this process the astronomical personnel of the Observatory is shown to be one in excess of that at Harvard, and the salaries are compared on this basis, greatly to the disadvantage of the Observatory. This enumeration also charges the Observatory with two "directors" for the same obvious reason. Although the board had no time to form an opinion, it should have learned, if it could have assimilated the information which it received, that the Observatory, like other naval establishments, has but one "head," and that the astronomical director of the Observatory is the head of the astronomical department, just as a naval officer is the head of the department of nautical instruments. To charge two "heads" to the Observatory in order to increase the apparent extravagance of maintenance is clearly a perversion of fact. If the Observatory has two heads then it has eight heads, one for each department, and including the superintendent.

The attention of the Bureau is asked to a comparison of salaries, shown in the above table, which forms the basis of the board's charge of extravagance. At both Greenwich and Harvard the salary of the director is $5,000. At the Observatory, using the board's own method of comparison, the corresponding salary is $3,500. But, by the ingenious device of a "dual head," the board increases it to $4,000 and then doubles it. Naval officers receive their pay, whether they happen to be on duty at the Observatory or elsewhere; but the board chooses to assume that the salary of every professor of mathematics in the Navy, active or retired, except two at the Naval Academy, is chargeable to the expenses of the Observatory. It therefore charges in its exhibit the salaries of officers on the retired list, and the salary of one officer, still on the active list, whose connection with the Observatory has long since definitely ceased for cause. By such flimsy expedients as these the expense column is easily swelled. It might be swelled to any amount desired by simply charging against it the salary of any or every living officer of the Navy, active or retired, who had ever been on duty at the Observatory. It is in the lower grades particularly, however, that I ask a fair comparison of salaries at the three institutions selected by the board. At Greenwich, for example, computers receive an average of $325 per year, less than one-half the pay of our laborers, and less than the remuneration of any human being doing skilled work in the United States. At Harvard computers receive an average of $600, less than the pay of any person in the United States Service. These computers are largely women, who can be got to work for next to nothing. Now the Observatory pays its employees at exactly the same (or in some cases less) rate as in other branches of the Government Service in corresponding grades. To charge extravagance against the Observatory because its employees are paid according to a rate fixed by law for the public service at large is clearly disingenuous and tending to mislead.

The whole report of the board is colored by the evident intention of making as strong a case against the Observatory, and in favor of its own plan of reorganization, as possible.

On page 6 the board objects to transferring responsibility of direction from the astronomical director to a committee, and then, on pages

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7 and 8, recommends that the board of visitors "shall prepare and submit to the Secretary of the Navy regulations prescribing the scope of the astronomical and other researches of the Naval Observatory and the duties of its staff with reference thereto." In other words, the duties which should belong to the astronomical director, if he is to be held responsible for the astronomical work of the Observatory, are to be transferred to the board of visitors. Furthermore, on page 14, it is proposed that the board of visitors shall have power to make "neces sary changes," apparently not only in the work but also in the personnel.

On page 8 objection is made to retiring astronomers at 62 years of age, as is now done, and on page 6 it is specifically recommended that under the proposed new arrangement the astronomical staff of the Naval Observatory are "to hold their offices until their successors are appointed," or, in other words, they are to have no tenure of office at all, and to be liable to dismissal at any moment.

The pay table on page 9 proposes to give the Astronomical Director $6,000 a year, and the Director of the Nautical Almanac, $5,000, making a total of $11,000 a year, for the same duties which were then performed by Professor Harkness for $3,500 a year. In view of the distinct charge of extravagance against the present administration, this proposal is only ludicrous. It is difficult to believe that it was intended to be taken seriously.

On page 12 it is asserted that the 9-inch transit circle was not then in use, although the board knew that it was simply undergoing periodical temporary repairs, and would be brought into use again as soon as they were completed.

On page 13 it is asserted that none of the directors of the Greenwich or Harvard College observatories "have ever resigned to accept positions elsewhere," but the author of the report forgets to mention that one of the Greenwich astronomers royal did resign.

On page 15 it is indirectly stated that when an observer is not actually observing he is only doing clerical work, which is untrue. The reduction of astronomical observations is not clerical work within the ordinary meaning of that phrase.

The statement on page 30 respecting the personnel of the Observatory board established by Rear-Admiral John Rogers is wholly erroneous. That board comprehended the entire astronomical staff of the Observatory.

In the list of professors of mathematics, given on page 41, Prof. H. M. Paul is stated to be attached to the Naval Observatory when in fact he is attached to the Bureau of Yards and Docks.

An historical sketch of the Naval Observatory, written by an individual member of the board, with the avowed purpose of showing that the system under which the Observatory has been administered since its foundation is entirely defective, is appended to the report. It is a sufficient criticism of this sketch to say that a system which, from a most modest beginning, has built up one of the few great astronomical institutions of the world, and which has produced the two most eminent living astronomers in America, can not be wholly bad.

It is particularly worthy of note that the board actually proposes to remove the affairs of the Observatory from Government control. The irresponsible governing authority of a public institution is to be "a board of visitors independent of Government control, but having power to make necessary changes." With the exception of

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this preposterous proposal, I will dismiss the plan of reorganization proposed by the board with the simple statement that subsequent events have made it impracticable, or at least highly unlikely to be seriously considered now. To apply it at the present time would be, not to build up, but to tear down.

A determined effort was made by the board to prevent, if possible, the appointment of new men to fill the vacancies created by the retirement of the older professors of mathematics at the Observatory. New offices were created in the board's plan of reorganization at enormous salaries. Notwithstanding the efforts of the board to prevent it, these vacancies have all been filled in line with the traditional policy of the Observatory, which has always been to take for its staff young men of promise whose career was before them, in contrast with the plan recommended by the board of appointing at once to high office men whose scientific reputation was already established, and whose prejudices and animosities were mature and confirmed.

I have ventured to touch in brief upon the report of the board of visitors in a manner which I trust does not transcend the legal limitations of this report, because, while the Observatory has been made the object of adverse criticism in the report, the friends and supporters of the board have not hesitated to assail it in attacks in the public prints, some of which have been extremely abusive and obviously dictated by pure malice, and with the knowledge that a reply in kind was impossible. This report furnishes the only means of replying to these attacks, which are and have been perennial, culminating in force whenever, as in the present instance, circumstances seemed to justify a reasonable anticipation of success.

The Observatory staff is now complete. The excuse afforded by the retirement of the older professors of mathematics no longer exists. For the present, at least, no person, no matter how eminent he may be in science, can pretend to be a friend of the Observatory or of science while attacking its organization. I do not mean to say that the Observatory should be exempt from criticism; but such criticism, in order to be of any benefit, must be made in a spirit of fairness, and not in a spirit of animosity. The Observatory invited such criticism from the recent board of visitors, and its invitation was slighted.

The observatory is making an earnest and honest effort to correct faults which have, in most cases, arisen from circumstances not wholly within its own control, as the board very well knew, but omitted to point out. It is only reasonable to ask that it be allowed a fair field for its efforts.

The experience with the recent board of visitors was not such as to encourage the hope that much good can be gained by a repetition of the experiment. Nevertheless, I recommend that a board of visitors be appointed from time to time, as may be convenient to the Department, not to act in an arbitrary and irresponsible capacity of authority, "free of government control," as recommended by the late board of visitors, but to give the observatory the benefit of its counsel and to give the scientific world an insight into the actual workings of the institution.

NAUTICAL ALMANAC.

The report of the Director of the Nautical Almanac is herewith transmitted.

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LIBRARY.

Assistant Librarian William D. Horigan has direct charge of the library, under the general supervision of the library committee.

	Volumes.	Pamphlets.	Total.
Contents of the library July 1, 1899	17,050	3,736	20,786
Accessions	550	81	631
Contents July 1, 1900	17,600	3,817	21,417

Of the accessions, 377 were received as exchanges and 254 were purchased.

I am, sir, your obedient servant,

C. H. DAVIS,
Captain, U. S. N., Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., August 13, 1900.

SIR: In compliance with paragraph 23 of the regulations for the government of the United States Naval Observatory, I have the honor to submit the following report concerning the operations of the astronomical department for the fiscal year ending June 30, 1900.

This department was in charge of Prof. William Harkness, U. S. N., until December 15, 1899, at which time he was relieved by myself preparatory to his retirement on December 17.

Upon assuming the duties of astronomical director my time was largely occupied for a month as a member of a board conducting a competitive examination for filling vacancies in the corps of professors of mathematics in the Navy, and in acquainting myself with the conditions of the work and instruments in this department.

On January 16 a more efficient distribution of the personnel engaged in the routine transit circle work, which had up to that time been in charge of Professor Skinner, assisted by a force of observers, including professors, assistant astronomers, and computers, was undertaken with the view of gradually utilizing more fully the available observing time of all the instruments. Professor See had been assigned the charge of the 26-inch equatorial on December 18, 1899, and Professor Updegraff to the charge of the 6-inch steel transit circle. The routine observations were, however, necessarily continued on this instrument in charge of Professor Skinner until the 9-inch transit circle should be in a condition for use. On January 16, 1900, the routine work on sun, moon, and planets was transferred to the latter instrument, with Professor Skinner in general charge of the instrument and observations; the observations and reductions of the revision zones to be carried on by Professor Skinner and Assistant Astronomer King; and the routine observations and reductions of the sun, moon, and planets by Professor Eichelberger, assisted by Computers Boeger, Brown, Lawton, and Hammond. Assistant Astronomer Littell was transferred to the 6-inch transit circle on February 7.

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THE 26-INCH EQUATORIAL TELESCOPE.

[Prof. T. J. J. See, U. S. N., in charge.]

On December 15, 1899, Professor See was placed in charge of the work on the 26-inch equatorial, which up to that time had been in charge of Professor Brown. It has been devoted throughout the year to the same general lines of research as in the past, consisting of observations of difficult double stars, satellites of the planets, and other objects suitable to a telescope of its optical powers.

Observations of close and difficult double stars have been made only on exceptionally favorable nights, while on less favorable nights easier pairs have been selected. One hundred and fifty measures of such objects have been secured by Professor See and twenty by Professor Brown. An orbit of τ Cygni, which revolves in a period of fifty-seven years, has been deduced by Professor See from available measures since 1874, and an approximate orbit of 95 Ceti, from which it appears that the period of revolution is about one hundred and fifty years, a much longer time than has hitherto been supposed. Both have been published in the Astronomische Nachrichten No. 3629, as well as a correction to Professor See's orbit of β 395, deduced from measures on two nights, indicating that the period will be reduced to about fourteen years, wh ch, if verified, makes this object one of the most rapid of visual binary stars. Professor See also announces in the same number of the Astronomische Nachrichten 3629, the observation on December 8, 1899, of the duplicity of 13 Ceti. This system has evidently made nearly half a revolution since Hough's discovery and earlier work in 1887, and is probably an important binary. The faint companions of Sirius and Procyon have also been measured and the results communicated to the Astronomische Nachrichten.

The experience of the past year in this line of work confirms that of the past few years, and shows that the theoretical limits of the object-glass can be obtained on the best nights, but the amount of fine weather in Washington is much less than can be had in other places with more favored climate. The installation of the insulating covering of the basement floor, spoken of in the last report of the astronomical director, has undoubtedly improved somewhat the unfavorable conditions for observing in cold weather, as it certainly has the usefulness of the instrument in making possible its use in the coldest weather of winter.

Observations of Neptune's satellite were secured on sixty-five nights, between October 6, 1899, and February 27, 1900. These measures have been reduced and compared with the elements of that satellite resulting from Professor Brown's previous investigations, to which they furnish slight corrections. The reduction and discussion of the observations was carried out mainly by Computer John C. Hammond, as a voluntary labor outside of his official duties, and the observations and results will shortly appear in the Astronomische Nachrichten, to which paper they have been sent for publication.

Observations of the two outer satellites of Uranus—Oberon and Titania—were begun on April 25, and have been continued on every night when they were visible. Up to July 1 only 20 observations have been secured, as, owing to the extreme southerly declination of the planet, the satellites can not generally be seen during the week preceding and following the full moon. The two inner satellites were occasionally glimpsed, but they could not be satisfactorily measured owing to their faintness.

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Observations of the four brighter satellites of Saturn—Titan, Rhea, Dione, and Tethys—were begun on May 5. Up to July 1 measures of Titan, referred to Rhea, were secured on 22 nights, and of Dione, referred to Tethys, on 15 nights, the relative positions of the satellites being measured in pairs, in order to avoid referring them singly to the center of the irregularly shaped planet.

During the hazy weather common here in the month of October, resulting in giving great steadiness to the images of celestial bodies, unusual at other times, Professor See noticed on several occasions some very faint markings on the disk of Neptune, which were ascribed by him to equatorial belts similar to those long known on Jupiter and Saturn. The fine definition at this time, aside from the steadiness of the image, was ascribed to the selective absorption of the haze caused by the smoke of forest fires, and experiments were carried out by Professor See and Mr. G. H. Peters to attain the same end artificially by the use of a color screen.

As a final result of the experiments three color screens were constructed by Alvan Clark & Son from designs by Professor See. The small cell consisted of two thin plates of plane parallel glass cemented to either side of the glass ring separating them, and the whole fitted in a brass adapter so as to bring it just outside of the outer lens of the eyepiece. Various fluids were used as absorbing media, depending upon the object to be attained, but generally such as to remove the blue rays, for which the telescope is imperfectly corrected, causing a troublesome violet-blue halo around all bright objects. On Mercury, Venus, Jupiter, Saturn, Uranus, and Neptune a solution of picric acid and chloride of copper in water was found most satisfactory, as it absorbs largely the red rays as well as the violet-blue. A solution of the bichromate or chromate of potash also performs well on bluish planets like Uranus and Neptune, and fairly well on Mercury and Mars. A preliminary account of the color screen was published in the Astronomische Nachrichten, No. 3636, and at the time it was supposed the experiments and results were entirely new. The editor of the Nachrichten, however, in an editorial note calls attention to similar experiments made in 1883 by Professor Mittenzwey, using as an absorbing medium a derivative of resorcin, known technically as fluorescein. His research was apparently carried no further than the experimental stage, sufficiently to demonstrate the practical advantages of the color screen in observations with large achromatic telescopes, and appears to have since remained unnoticed until the publication of the experiments and results in the Astronomische Nachrichten of April, 1900.

When the light is transmitted through the absorbing fluid, in addition to the removal of the violet-blue halo resulting from uncorrected chromatic aberration the image is somewhat steadied and the limbs of the planets thereby considerably sharpened. On account of these advantages measures of the diameters of the planets and measurable satellites have been made, excepting Mars, and it is proposed to continue the investigations during the present year.

The resulting diameter of Neptune, from measures on four nights, indicate a diameter of 2″.00, which is considerably less than recent measures with telescopes of large dimensions. The diameter found by Professor Barnard with the Lick 36-inch telescope is 2″.43, and by Prof. Hermann Struve with the 30-inch Pulkowa telescope is 2″.19.

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Professor Struve's result, which is the smallest value heretofore obtained, was derived from a series made with field illumination of different colors, by which the effect of the secondary spectrum would to a certain degree be removed.

Measures of the diameter of Uranus on 22 nights, with the color screen give a result of $3''.30 \pm 0''.005$, which is also smaller than recent results with large telescopes. Professor Barnard's value of this diameter, determined at the Lick Observatory, is $4''.15$, and he also finds a considerable ellipticity of figure. With the observations of the Washington telescope the disk was always found sensibly round, an oblateness of one eighty-third being indicated, which is probably not real.

A large number of observations of the diameters of Jupiter and Saturn have been made, and the series is to be continued throughou the present and during the next opposition.

Measures of the diameter of Venus have been secured on 17 days near inferior conjunction. The effect of the color screen in improving the definition in observations made in daylight is quite as decided as in observations at night.

Observations of the diameters of Jupiter's satellites indicate, as in the case of Neptune and Uranus, a considerable reduction of the measured diameters. How much of this decided tendency, which affects apparently only objects of small diameter, may be due to personal equation or to the absorptive effect of the color screen, can not be determined until comparisons shall have been made with observations without its use, and also with observations with the same device by other observers with instruments of suitable power.

All observations of double stars made by Professor Brown from 1896 to December 17, 1899, have been collected and published in the Astronomische Nachrichten, Nos. 3645–3646.

But little work was done with the spectroscope during the last fiscal year, as the previous investigations had shown the necessity for considerable alteration of the apparatus before it would give results suitable for the delicate investigations for which it is intended. The two new triple lenses for the camera and collimator were received from Mr. Brashear on March 23, and a few photographs taken to test their performance. Unfavorable weather and the demands of preparation for the observations of the eclipse of May 28 prevented any work beyond preliminary trials for the focus of these lenses.

THE 9-INCH TRANSIT CIRCLE.

[Prof. A. N. SKINNER, U. S. N., in charge; Prof. W. S. EICHELBERGER, U. S. N., in charge of sun, moon, and planet work.]

This instrument was undergoing repairs and alterations from the beginning of the fiscal year until January 20, 1900, during which time the routine observations of sun, moon, and planets were carried on with the 6-inch transit circle. The repairs consisted of recutting the faces of the marble piers supporting the instrument, rebuilding the nadir box, moving the west pier north twenty-five one-hundredths of an inch to bring the azimuth screws to the middle of their adjustment, and the mounting of the lanterns for illuminating the microscopes and telescope either by electric or gas light.

Although there yet remained other important changes which ought to have been made, the experience with the 6-inch transit circle had

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indicated equally the desirability of minor alterations and investigations of some peculiarities in order to make its performance satisfactory, and the work on the sun, moon, and planets was therefore transferred to the 9-inch transit circle on January 20, 1900.

This instrument is, in its essential features, the old Pistor & Martin's transit circle used in the old Observatory from 1866 to 1892, but in the attempt to improve it by extensive alterations the importance of providing a symmetrical illumination in the place of the old one appears to have been entirely overlooked. The unsymmetrical illumination of the field, which seems to be one of the few objectionable points of the Pistor & Martin's instruments, not only produces liability to systematic errors in both right ascension and declination, but also introduces liability to errors in the determination of the constants and of observations of stars, which, although small, ought not to be tolerated in a modern instrument. With this feature of the instrument remodeled, as it can be at comparatively small cost, it will be in a condition for any kind of observations which may be required of a meridian circle. As the errors may be partially avoided by the exercise of careful precautions, it will continue to be actively used until a more favorable time than the present arrives for its repairs.

Upon the resumption of the regular work (in order to expedite the completion and publication of the Southern zone), Professor Skinner was placed in charge of the zone work, to which, with the assistance of Assistant Astronomer King, he will devote all of his time. Professor Eichelberger was placed in charge of the routine sun, moon, and planet work on the same instrument, assisted by Computers E. A. Boeger, W. M. Brown, G. K. Lawton, and J. C. Hammond, and until February 7 by Assistant Astronomer Littell. At the same time some changes were introduced in the general method of carrying on the routine observations and reductions by which the flexure will be taken into account in deriving the equator point from which the differential declinations will be determined. In the determination of this constant in the daytime there is frequently a wide range of declination in the fundamental stars used for this purpose, and unless the equator point thus derived is corrected for flexure there will be liability of the introduction of systematic errors.

ZONE OBSERVATIONS —13° 50′ TO —18° 10′.

During the year the observations of zone stars have been confined to a revision of the zones previously observed, in order to explain or correct discrepant results. The number of observations made during the year is as follows:

Zone stars	910
Zero stars	204

It is expected that the revision observations will be completed before December 31, 1901. The reductions of the zone observations to 1900 have been completed and the results entered in the card catalogue. The results have been inspected for discrepancies, and discrepant stars have been selected for reobservation. The reduction of these revision observations is kept as close as possible up to date, in order to bring this part of the work to an end as early as practicable. With the force of computers now available it is hoped that the first volume of zone observations will be ready for the printer by January 1, 1901.

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SUN, MOON, AND PLANET WORK.

The following table shows the number of observations of each object on each instrument during the year ending June 30, 1900:

	6-inch transit circle.	9-inch transit circle.	Total.
Ephemeris stars	1,345	843	2,188
Sun	93	52	145
Moon	89	65	154
Mercury	43	29	72
Venus	69	49	118
Jupiter	.....	6	6
Saturn	6	3	9
Uranus	3	4	7
Neptune	20	.....	20
Miscellaneous stars	73	.....	73
Wire interval stars	158	78	236
Longitude stars	.....	77	77
Total	1,899	1,206	3,105

The reductions are completed through March, 1900. The copy for the printer is completed through June, 1898, and the copy for 1899 will be in the hands of the printer before October 1, 1900.

THE 6-INCH STEEL TRANSIT CIRCLE.

[Prof. MILTON UPDEGRAFF, U. S. N., in charge.]

As stated in the paragraph concerning the 9-inch transit circle, the routine observations of the observatory were carried on on this instrument from July 1, 1899, to January 20, 1900, in charge of Professor Skinner. On December 18, 1899, Professor Updegraff was assigned to the charge of the instrument to give such time to the investigation of it as was possible without interfering with the routine work.

The experience gained in the observations, as well as their final results for the preceding portion of the year, had shown that the instrument, owing to lack of sufficient investigation and preliminary observations was hardly in a condition to use for the routine work of the observatory. There had been developed the necessity of various repairs and alterations in the instrument and its accessories, as well as a more careful and extensive investigation of its performance than was feasible while using it for daily work on the sun, moon, and planets. The repairs and alterations, although principally of a minor character, were numerous and required considerable time, while the investigation to test its suitability for work of the highest accuracy must necessarily be extensive. The necessary observations for this purpose have been laid out with the object of securing as far as practicable results of immediate value in astronomy.

On February 7 Assistant Astronomer Littell was assigned to this instrument as a regular observer, and observations were begun on February 13. The observation list comprised 135 stars selected from Gill's Zodiacal Catalogue, for the special purpose of heliometer observations of the planets Neptune, Jupiter, Saturn, and Mars. This work is well advanced toward completion, and the results will be published as soon as practicable in the current astronomical journals. A further list of 45 ephemeris stars, distributed widely in declination, has been observed in both right ascension and declination and in both positions of the clamp, with a view of testing the performance of the instrument

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more thoroughly. The observations in declination are made with the fixed pair of threads in the field of the telescope by moving the telescope with the slow-motion screw so as to bring the star midway between the pair of threads, which are 9 seconds apart. All observations in declination have been referred to the nadir point, which was observed in an analogous manner, no use being made of the micrometer screw, as is the custom with the 9-inch transit circle. When an assistant is present both circles are read, and an observation in declination consists of two settings on the star and a reading of four microscopes on each of the two circles. When both circles are read in this manner the probable accidental error at moderate zenith distances of a single observation in declination is $\pm$ 0″.22.

This instrument is made entirely of steel and mounted very solidly, so that the constants might reasonably be expected to be unusually steady. In the case of the level and collimation this expectation has been realized, but not in the case of the azimuth. Both the collimation and the level are remarkably uniform, excepting that on one or two occasions the latter has shown slight though anomalous changes. A series of experiments made in November, 1899, showed that the variation of the azimuth keeps pace regularly with the variation of the temperature of the steel in the microscope bearers on which the pivots rest. This variation is not, however, a linear function of the temperature, but is less per degree at low than at high temperatures. The change of azimuth per degree of temperature (Fahrenheit) during the earlier part of its use seems to have been 0ˢ.032. Since the instrument is provided with a meridian mark to the north, this variation of the azimuth has been productive principally of inconvenience rather than inaccurate work; but the change is too great to make the instrument a suitable one for fundamental work. The instrument will in the near future be entirely dismounted and a careful investigation made in the hope of finding the source of this variation.

Except during the month of May, when work was temporarily suspended on account of the absence of both Professor Updegraff and Mr. Littell in connection with the total eclipse of May 28, observations were made on almost every clear night from February 13 to the end of the year covered by this report. Naturally much labor has been expended on the determination and investigation of the constants of the instrument. A summary of observations made during the period February, 1900, to June, 1900, follows:

Observations of stars.

Observations of Polaris for latitude and azimuth	26
Zero and ephemeris stars	395
Zodiacal catalogue stars	744
Thread interval stars	72
Total	1,237

Determinations of instrumental constants.

Determination of collimation	99
Determination of azimuth of instrument	195
Determination of level	145
Determination of azimuth of mark	26
Determination of error of runs	52
Determination of nadir points	268
Total	785

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It is intended to use this instrument principally in observing the fixed stars, and to adapt it, as far as may be possible under the conditions, to fundamental work of a high degree of accuracy.

For the immediate future this work will consist of the determination of the positions of 205 zero stars for the catalogue of 2,798 zodiacal stars arranged by Sir David Gill, director of the Royal Observatory, Cape of Good Hope, in accordance with the resolutions of the Conference on Fundamental Stars, held in Paris in 1896. There will also be included, as in the past, stars from Newcomb's Fundamental Catalogue, for the purpose of the investigation of the instrument and as the basis to which the Gill zero stars will be reduced.

THE 12-INCH EQUATORIAL TELESCOPE.

This instrument was in charge of Professor See from July 16 until December 17, 1899, since which date I have had it under my general charge, in order to test for myself the complaints of its unsatisfactory performance by those who have observed with it. It has been used, as in the past, for observations of comets, asteroids, and other miscellaneous objects. Those made by Professor See, and which were published in the Astronomische Nachrichten, No. 3626, were as follows:

Antiope (90), 7; Leto (88), 5; Elvira (277), 3; Minerva (93), 8; Comet V 1899, 2.

A careful investigation of the micrometer screw was published in the same paper, giving the value of a revolution as follows:

366 transits of circumpolar stars	22″.890
120 measures on four stars of the Pleiades	22″.879
Mean	22″.885±0″.002

for scale reading 462 and temperature 50° F.

A careful investigation of the instrument convinces me that its efficiency would be greatly increased by a general change in the details of its mountings and accessories. Plans are now under discussion, submitted by the firm of Fauth & Co., its makers, which it is hoped will remedy the principal defects. The proposed changes consist of:

1. The separation and mounting on separate axes of the two wheels for quick motion, which now revolve on a common axis, so that frequently motion in one coordinate produces a change in the other.

2. Separation of the clamping and slow-motion handles on the tube, which now operate at times only with the application of considerable force and with the result of unclamping the instrument in right ascension.

3. Remodeling of the head casting, which is necessary to effect changes above mentioned and give a more direct and positive clamping and slow motion in right ascension.

THE PRIME VERTICAL TRANSIT INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

The work on this instrument has been devoted to observations of α Lyræ and a small list of suitable stars for the purpose of investigating the variation of latitude and the constants of nutation and aberration. The number of observations is as follows:

α Lyrae	89
Other stars	75

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A careful investigation of the level constant, with a special reference to the coincidence and parallelism of the axis of the pivots, is in progress, but the material is not yet sufficient to determine whether any defect exists in regard to this which is of sufficient magnitude to affect the observations. All the observations are reduced up to date, and, together with the observations on the alt-azimuth instrument for the same purpose, have been furnished in manuscript up to January, 1900, to the Centralbureau der Internationalen Erdmessung, to be used by Professor Albrecht in his annual memoir on the condition of the investigations of the latitude variation at the end of the year 1899.

THE 5-INCH STEEL ALT-AZIMUTH INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

This instrument is used principally as a zenith telescope for observations of latitude by Talcott's method and the declinations of the stars of the American Ephemeris. Of the former there have been made 86 observations of α Lyræ and 3 of miscellaneous stars, which are reduced up to date, and the results to January, 1900, together with the material from the prime vertical instrument, sent to Professor Albrecht. Of the declinations of Ephemeris stars 330 observations have been made, and the reductions are completed up to the end of the calendar year.

The results have not yet been subjected to sufficient study to determine the quality of the instrument for obtaining absolute declinations, for which purpose the general form of the mounting is admirably adapted. When its usefulness in this field is established I propose to separate the work of the two instruments and employ more observers in this important line of observation. I have not thought it expedient to attempt this until the arrears of publication are brought up—a task on which all the available force of the Observatory is now concentrated.

THE 40-FOOT PHOTOHELIOGRAPH.

[Photographer GEORGE H. PETERS, in charge.]

The series of daily photographs of the sun has been continued, weather permitting, except after April 2, when they were interrupted by the preparations for the observations of the total eclipse in May. Negatives were obtained on 81 days, showing sun spots on 18, distributed as follows: Two in September, 2 in December, 5 in January, 5 in February, 3 in March, and 1 in April. Visual observations of the sun in May indicate the same low state of solar activity.

In December the glass reticule plate, used in the transit of Venus observations for determining any possible distortion of the film, but which was of no value for sun-spot photographs, was removed, as the thick glass plate placed about a quarter of an inch in front of the focal plane of the object glass was a serious obstacle to good definition, on account of the multiple reflections of light forming the sun's image between its plane surfaces. At the same time the dry plate was substituted for the wet collodion process previously used, and the plates backed. Upon focusing the apparatus anew a great gain was apparent in the definition of the lens and the amount of detail shown on the solar surface, so that it is now possible to obtain a negative showing a great deal of detail in the spots and faculæ.

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INSTRUMENTAL CHANGES.

March 5, 1900, the Clark micrometer No. 2, which had been provided by Warner & Swasey with a modern and efficient electric illumination, was installed on the 26-inch equatorial in place of the old Clark micrometer. The latter had been in service since 1873, but though still serviceable was provided with illumination only by a small hand lamp held by an assistant. This method was not only inconvenient, but caused an unsymmetrical illumination which might produce systematic error in observations. The new micrometer was made by Mr. George Clark in 1874, but has since been used only in the determination of its constants, and represents the finest workmanship of a gifted mechanic. The screw was investigated by Professor Holden in 1876 (Washington Observations, 1877, Appendix I), and the value of a revolution fixed at 9″.300. The preliminary value adopted by Professor See from transit of circumpolar stars and measures on Atlas and Pleione of the Pleiades is 9″.928 ± 0″.001. Thus far his investigation shows no temperature coefficient, although the observations for this are not yet completed. Experience with this instrument in the past indicates that this will be an inappreciable quantity. The illumination by a small 2-candle electric lamp with current from seven Edison-Lalande cells is symmetrical, steady, and capable of adjustment to any desired color or intensity. While the box containing the lamp becomes noticeably warm, it is so insulated from the micrometer box that it can hardly produce any appreciable effect on the micrometer screw.

Both the 6 and 9 inch transit circles are to be provided with mirrors or meridian marks to the south, duplicates of the ones already to the north of the respective instruments, except that in case of the 6-inch the distance from the instrument on account of the nature of the land toward the south can be only about 175 feet instead of 380. The lenses, mountings, and meridian marks were ordered in April from Messrs. Warner & Swasey, and will be installed immediately upon their arrival, which is promised by the end of August at the latest. The object of this additional mark to the south is to eliminate the liability of systematic errors in the azimuth due to error of assumed collimation, which will affect the azimuths resulting from the north and south marks with opposite signs.

THE SOLAR ECLIPSE OF MAY 28, 1900.

As soon as it was ascertained that Congress had appropriated money for carrying out the observations for this important event, I began the formation of general plans for the work, including alterations in instruments already possessed by the Observatory, and designs for new ones. In the formation of parties, the selection of the most important lines of investigation, and suitable instruments for the purpose, the general interest of scientists in the event was recognized by inviting the cooperation of specialists in the spectroscopic and physical research, and it is gratifying to state that this invitation was generally accepted, so that a considerable portion of the actual work of preparing for and observing the eclipse was shared by many scientific institutions of the country.

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To avoid as far as practicable unfavorable weather, two widely separated stations were selected, one at Pinehurst, N. C., and one at Barnesville, Ga., both near the central line of totality. For certain advantages in spectroscopic work a third station was chosen at Experiment, Ga., near the northern limit of the shadow path. Notwithstanding the efforts to get all apparatus in readiness so that at least a month would be available for erecting and testing the instruments, the delays and failures of instrument makers prevented the erection of some of the important ones until only four or five days before the eclipse. This delay, which caused the failure of some of the most carefully planned instruments, might have been avoided if the Observatory were supplied with a small machine shop, the possession of which enabled other expeditions to occupy their stations fully a month before the eclipse. The general programme of observations comprised the following objects:

1. Establishment of accurate geographical position of stations.
2. Sketches of corona, both naked eye and telescopic, and telescopic study of physical structure.
3. Photographs of corona.
4. Spectroscopic observations of "reversing layer" and corona, both visual and photographic.
5. Polariscopic observations of corona, visual and photographic.
6. Observations of contacts and determination of the limits of the shadow path.
7. Observations of "shadow bands" and general phenomena.

The instruments to carry out this programme were, from the nature of the case, often expressly made, and yet were required to be mounted with such care in rude temporary shelters that the brief time of eighty or ninety seconds might be utilized to secure with certainty observations of the greatest delicacy and precision. The endeavor was made to devise instruments and methods which would enable us to make a distinct advance on previous eclipse work. In several lines this was successfully done, notably in the matter of spectroscopes, in which gratings were generally substituted for glass prisms. Two of these, with several quartz lenses, were purchased with special reference to eclipse work, and will form a valuable addition to our apparatus for future work in this line, as well as in the investigation of the spectra of stars and motion in the line of sight.

While there were failures with some of the instruments, due to lack of time for properly mounting and testing them, I am happy to state that the programme was, as a whole, successfully carried out, and valuable material secured which is now in process of study and investigation. As it is proposed to publish within a few months a detailed report upon the eclipse expeditions and results, a fuller statement is not thought desirable.

In this connection your attention is invited to the importance of an early appropriation for the observations of the total eclipse of May 17, 1901, which is in many respects the most remarkable of the century, on account of the long duration of totality of six and one-half minutes and the high altitude of the sun. It can be observed to advantage only in the islands of Sumatra and Borneo, and perhaps a few other small islands of the East Indies. The Observatory has an unusual advantage on account of the facilities which may be afforded by its

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transport service and the presence of many naval vessels in that region. The special instrumental equipment now on hand and the experience acquired in the recent eclipse place this Observatory in a position ot do great service to science, which the expense involved will almost preclude private expeditions from assuming. Already Holland is preparing for its observations, and Great Britain will most probably follow its custom of sending an expedition in a naval vessel.

STANDARD CLOCK.

Preparations are now in progress for installing a standard clock in a hermetically sealed case to be kept in a double-wall chamber at a constant temperature. The device for keeping the temperature constant is entirely similar to that now employed so successfully in the temperature room for testing chronometers. I consider this subject as one of the most important for the future of the fundamental work of the Observatory, and no pains or expense ought to be spared in securing the best possible performance of a standard clock under the conditions above described. I regret that the preparations for the eclipse so completely occupied the resources of the Observatory that this important matter has had to be laid aside until the present time.

PUBLICATIONS.

The volumes for 1891 and 1892 are still in the hands of the Government Printer awaiting some changes in, or additions to, the appendix for 1891, containing "Observations of the transit of Venus, December, 1874, part 2." These changes are to be made by my predecessor in this office, now on the retired list, by virtue of an arrangement made previous to his retirement with the Superintendent of the Observatory. As I was not consulted by my predecessor in regard to this arrangement, nor given any information concerning the nature of the further work to be done on the appendix mentioned, I am not in a position to accept the responsibility for the future of those two volumes.

The future publications of the Observatory, other than these, will be continued as Washington Observations, second series, beginning with the removal to the new Observatory in 1893. The volumes of this series will be classified, and each one will contain only the material pertaining to its title. As far as planned, they will be as follows:

Volume I, Observations of the Sun, Moon, and Planets, 1894–1899.

Volumes II and III, Observations of the Southern Zones, $-13^\circ\ 50'$ to $-18^\circ\ 10'$.

Volume IV, Zone Catalogue of Stars, $-13^\circ\ 50'$ to $-18^\circ\ 10'$.

The other volumes will be devoted to the work on the different instruments, as well as some valuable material extending back into the early history of the Observatory.

With the increased computing force provided by the last session of Congress, it is intended to prepare for publication, at an early date, the Washington Zones, made during the years 1845–1851, but the current work will not be neglected in order to accomplish this task, so important to the reputation of the Observatory. The observations of the Gilliss Zones, made in 1850–1852, will, after that, be taken in hand. There is no doubt as to the advisability and desirability of publishing

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these zones, not only on account of their value, but as a memento to the activity of the late Captain Gilliss, whose death prevented their timely publication.

Very respectfully,

STIMSON J. BROWN,
Professor of Mathematics, U. S. N., Astronomical Director.

The SUPERINTENDENT, U. S. NAVAL OBSERVATORY,
Georgetown Heights, D. C.

DEPARTMENTS OF NAUTICAL INSTRUMENTS, AND OF THE GENERAL STOREKEEPER.

SIR: The general storekeeper's department has kept up the preparation of requisitions for the purchase of new articles and for repairs to old ones, the inspection of stores, and the issue to ships and naval stations.

The appended list shows the purchases of new stores and of the issues made in the ordinary routine during the fiscal year ending June 30, 1900:

Stores received and issued by general storekeeper's department.

	Received.	Issued.
Artificial horizons		19
Bottles mercury		1
Sextants:		
High-grade	30	16
Squadron angles		18
Hydrographic	20	46
Spare glass for	24	61
Octants		13
Parallel rulers:		
Sigsbee		9
Ordinary		68
Clocks, deck	87	50
No. 2	100	52
Boat	124	26
Protractors, three-arm		19
Drawing instruments, boxes	25	19
Dividers, navigator's		19
Tapes, steel		14
Thermometers:		
Maximum and minimum	72	26
Air and water	335	212
Psychrometers	44	14
Spyglasses:		
Low-power	30	30
Medium-power	100	30
High-power	50	23
Officer of deck		35
Binoculars:		
Day	50	87
Night	100	122
Barometers, aneroid	66	22
Clinometers:		
Hicks	50	26
Fluid, bottles	100	54
Fluid, droppers	100	12
Reading glass, captain's		13
Splines and weights		15
T squares		9
Automatic tide gauges	3	3
Magnetometers	3	1
Dip circles	3	1
Telemeters rods	4	4
Transit, surveyor's		1
Transits and zenith telescope combined	1	2
Chronographs	1	2
Theodolites		2

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Stores received and issued by general storekeeper's department—Continued.

	Received.	Issued.
Plane table		1
Triangle		1
Steel scale, standard	1	1
Sounding tubes:		
Tanners'	488	488
Cases	24	24
Shields	49	49
Scales	24	24

In addition to the ordinary routine work, this department has been charged with the assembling, inspecting, marking, and packing of six complete outfits for hydrographic survey in the Philippine Islands, and has under way four additional outfits for hydrographic work and two outfits for the telegraphic determination of longitude. The labor connected with the preparation of these outfits has been far greater than the routine work of former years, and as it seems likely that the Bureau of Equipment will lay out more surveying work in the future than it has in the past, I beg to recommend a reorganization of the working force of this department of the Observatory. Heretofore the books have been kept by the Superintendent's clerk when he could find time from other duties; and all that relates to the handling, packing, marking, and custody of stores to one, and sometimes two, unskilled laborers from the grounds.

The aggregate value of the instruments purchased and received from navy-yards and other sources during the year amounted to $51,087.73. There were made 136 shipments of instruments, the invoice value of which amounted to $40,123.08.

There has been no personnel belonging to the department except the head of the department. A better organized and more responsible force is urgently needed if the work of the department is to be performed in an efficient manner. It has been impossible in the last few years to get as many line officers assigned to duty here as in former years, and the force will apparently have to be made up of civilians. I recommend as a suitable force to assist the head of the department:

1 clerk and bookkeeper.
1 skilled laborer.
1 unskilled laborer.
1 computer to determine the corrections of navigating and surveying instruments.

This latter work could be paid for per diem under "Increase of the Navy" according to the number of hours employed.

Very respectfully,

B. W. HODGES,
Lieutenant-Commander, U. S. N.,
Head of Department and General Storekeeper.

DEPARTMENT OF CHRONOMETERS AND TIME SERVICE.

SIR: During the early part of the year twelve new chronometers were purchased without trial. Of those that passed through the trial seven were purchased. Five standards and three hacks were reported during the year, which were either purchased with ships or captured during the Spanish war.

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The following table includes the chronometers at Mare Island, Cal., in addition to the same for the Observatory, and shows the number received and issued during the year:

	Purchased—		Returned from—			Condemned to be hacks.	Converted from standards.	Issued to—			Condemned to be hacks.	Converted from standards.
	New.	With ships.	Ships.	Shore stations.	Makers.			Ships.	Shore stations.	Makers.		
M. T. standards	19	5	49	1	48	0	0	62	2	38	1	5
M. T. hacks	0	3	15	0	16	1	0	22	0	13	0	0
M. T. brk. circ	0	0	0	1	1	0	1	0	3	0	0	0
Sid. brk. circ	0	0	0	1	4	0	4	1	1	6	0	0
Sid. standards	0	0	1	1	0	0	0	1	0	0	0	0
Thermometric	0	0	0	0	2	0	0	0	0	0	0	0

The following table shows the present location of all the seagoing chronometers belonging to the Navy:

	In service, afloat.	At Mare Island.	At shore stations.	Ready for issue.	Undergoing repairs.	Total.
M. T. standards	215	24	10	56	32	337
M. T. hacks	61	7	19	10	4	101
M. T. brk. circ	1	1	6	0	0	8
Sid. brk. circ	3	2	5	1	4	15
Sid. standards	0	1	0	1	0	2
Thermometric	0	0	4	0	0	4
Pocket	0	0	0	5	1	6
Total	280	35	44	70	44	473

Besides the above, there are 26 worn-out hacks which are condemned for use at the Observatory. But few of these are of any use. Twenty-one chronometers are held at the Observatory on account of their historical interest.

On July 12, 1899, a requisition was made for the purchase of 12 standard chronometers after a competitive trial, and notice was sent to the principal firms of chronometer makers in the United States.

Only two firms entered chronometers under the notice, the other firms being deterred by the fact that during the war with Spain they had sold off their stock of chronometers and did not have any that they themselves considered fit for competition.

Of the two firms that competed, H. H. Heinrich, of New York, entered 11, and Wm. Bond & Son, of Boston, entered 4. Of the 15 under trial, one—H. H. Heinrich, No. 1037—had a trial number small enough to be accepted under the specifications, at the price of $330; but with the consent of the Bureau of Equipment 6 others—H. H. Heinrich, Nos. 1052, 1051, 1045, and Wm. Bond & Son, Nos. 551, 544, and 534, were purchased at a reduced price of $250 each.

The poor showing made by the chronometers was ascribed by the makers to the fact that the chronometers were new and unseasoned. In addition to the chronometers entered as above by the makers, 34 of the Bureau's chronometers were put through the same test for the determination of new rate curves.

The temperature-room trial began on December 19, 1899, and lasted until March 17, 1900. The apparatus for cooling, heating, and regulating the temperature gave satisfactory results.

The chronometer-room trial began on March 20 and lasted to June 12, 1900.

The following table shows the detailed results of the trial:

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Relative number.	Repaired by—	Chronometer number.	Maker.	Dec. 19 to Dec. 26	Dec. 28 to Jan. 4	Jan. 7 to Jan. 14	Jan. 18 to Jan. 25	Jan. 27 to Feb. 3	Feb. 5 to Feb. 12	Feb. 15 to Feb. 21	Feb. 26 to Mar. 5	Mar. 10 to Mar. 17	Mar. 20 to Mar. 27	Mar. 27 to Apr. 3	Apr. 3 to Apr. 10
Time															
Temperature, Fahrenheit.....degrees..				45.8	54.9	70.0	85.0	90.0	85.1	69.9	55.2	45.3	65.8	64.5	66.5
Relative humidity .....per cent..				68	68	70	68	71	70	71	66	72	51	52	52
1	.....	2941	John Bliss & Co	−1.47	−2.63	−3.26	−2.74	−2.16	−2.61	−3.45	−2.96	−1.89	−4.06	−4.16	−4.30
2	Bond	49238	Dent.....	+2.29	+1.59	+1.31	+1.53	+1.53	+1.30	+1.18	+1.10	+2.03	+0.69	+1.03	+1.27
3	.....	554	Wm. Bond & Son	+0.20	−1.29	−2.21	−1.57	−1.33	−1.61	−2.23	−1.47	−0.16	−2.24	−2.26	−2.47
4	Negus	1281	T. S. & J. D. Negus	.....	+1.80	+1.46	+1.64	+2.27	+1.96	+1.52	+2.66	+3.80	+1.99	+2.01	+1.91
5	Bond	548	Wm. Bond & Son	+2.00	+1.04	+0.66	+1.47	+2.07	+1.91	+1.23	+1.46	+2.77	+0.47	+0.36	+0.24
6	.....	558	.....do	−1.63	−2.10	−1.86	−0.53	+0.36	−0.40	−1.83	−1.76	−0.51	−2.74	−2.69	−2.87
7	.....	2934	John Bliss & Co	+0.41	−0.39	−0.93	−0.04	+0.81	+0.54	−0.12	+0.13	+0.99	−1.00	−0.97	−1.11
8	Negus	1850	T. S. & J. D. Negus	.....	+0.44	−0.15	+0.31	+0.60	−0.17	−0.70	+0.53	+2.06	−0.17	−0.19	−0.40
9	Negus	1710	Clerk	+1.53	+0.47	+0.07	+0.71	+1.60	+1.37	+0.50	+0.90	+2.59	+0.09	+0.06	−0.11
10	.....	556	Wm. Bond & Son	+0.77	−0.56	−1.79	−1.93	−1.21	−1.61	−2.15	−1.33	+0.37	−1.89	−1.86	−1.91
11	Negus	1074	T. S. & J. D. Negus	.....	−0.06	−0.83	+0.23	+0.71	−0.01	−0.83	+0.23	+1.44	+0.11	+0.14	+0.10
12	Negus	1265	.....do	+0.96	−0.64	−1.29	−0.39	+0.06	−0.59	−1.65	−0.66	+0.73	−1.49	−1.56	−1.83
13	.....	518	Wm. Bond & Son	+1.56	+0.13	−0.71	+0.19	+0.81	+0.53	−0.37	+0.57	+1.73	−0.29	−0.43	−0.73
14	Bond	221	.....do	−0.36	−0.03	−0.53	−0.11	−0.21	−0.47	−0.70	−0.90	+0.30	+0.73	+0.99	+0.99
15	Negus	1291	T. S. & J. D. Negus	+2.34	+1.43	+1.21	+2.51	+3.41	+3.01	+1.63	+1.89	+2.73	+1.26	+1.24	+1.21
16	Bond	218	Wm. Bond & Son	−0.59	−1.77	−2.10	−1.14	−0.47	−0.73	−1.27	−0.79	+0.16	−1.39	−1.43	−1.56
17	Bond	293	.....do	+0.86	−0.74	−1.71	−1.14	−0.61	−0.84	−0.90	+0.17	+1.73	−0.50	−0.16	−0.23
18	Negus	1655	T. S. & J. D. Negus	+2.79	+2.19	+2.71	+4.21	+2.85	+2.91	+2.92	+2.60	+3.04	+2.79	+2.81	+2.77
19	.....	2937	John Bliss & Co.....	−3.71	−3.77	−3.43	−3.19	−2.40	−2.33	−2.53	−2.80	−3.09	−4.17	−4.64	−5.16
20	.....	2949	.....do	−1.54	−2.86	−3.50	−2.83	−2.50	−2.66	−3.57	−3.26	−2.41	−4.44	−4.69	−5.00
21	.....	557	Wm. Bond & Son	−3.00	−2.61	−1.41	−1.39	−1.31	−1.76	−2.28	−3.24	−3.81	−3.04	−2.79	−2.23
22	.....	48831	Dent.....	−2.14	−0.87	−0.60	−0.90	−0.93	−1.04	−1.37	−2.46	−1.41	−2.67	−2.69	−2.73
23	Negus	725	T. S. & J. D. Negus.....	+2.50	+2.19	+1.29	+1.40	+1.50	+1.51	+1.53	+3.03	+4.40	+2.33	+2.17	+2.03
24	Heinrich .	1016	H. H. Heinrich.....	+4.31	+3.86	+3.43	+2.54	+2.39	+2.60	+1.93	+2.83	+4.61	+2.84	+3.01	+2.96
25	Bliss.....	2829	John Bliss & Co.....	+5.39	+3.33	+0.77	+0.61	+0.70	+1.13	+1.67	+2.21	+3.51	+1.87	+1.70	+1.43
26	Bond	493	Wm. Bond & Son.....	−1.16	−1.24	−0.86	−0.14	+0.63	+0.41	−0.20	−1.80	+0.09	−0.36	−0.29	−0.33
27	Bond	2851	Frodsham	+2.03	−0.49	−0.36	+1.54	+3.01	+2.49	−0.17	0.00	+1.20	−0.60	−0.69	−0.64
28	Bliss.....	49461	Dent.....	+6.27	+3.54	+1.93	+1.71	+1.46	+1.49	+1.25	+2.40	+3.27	+2.29	+2.36	+1.96
29	.....	553	Wm. Bond & Son.....	−1.37	−1.70	−3.26	−2.86	−1.16	−0.76	−1.45	−1.61	−1.30	0.00	+0.33	−0.01
30	Bliss.....	2860	John Bliss & Co.....	−0.77	−1.67	−1.86	−1.10	−0.70	−0.69	−2.62	−0.41	−0.49	−0.86	−0.81	−1.03
31	Bond	4667	Johannsen	−5.19	−4.59	−4.64	−4.21	−4.04	−3.13	−2.90	−3.40	−2.73	−3.14	−2.97	−2.73
32	Bond	272	Wm. Bond & Son	−1.09	−2.10	−0.97	+0.46	+1.20	+0.99	+1.25	−0.04	−0.81	−0.29	−0.36	−0.40
33	.....	47667	Dent.....	−3.80	+0.31	+0.43	+0.74	+1.06	+0.99	+0.73	+0.36	−2.01	+0.50	−0.17	−0.46
34	Bond	555	Nieberg	+0.64	+0.86	−0.11	+4.27	+5.60	+5.77	+5.13	+3.96	+6.44	−0.81	+2.00	+2.39
1	.....	1037	H. H. Heinrich	+2.71	+1.29	+0.11	+0.53	+0.60	+0.63	+0.55	+0.99	+2.34	−0.60	−0.40	−0.37
2	.....	1041	.....do	+0.86	−0.27	−0.50	+0.76	+1.53	+1.06	−0.13	+0.57	+1.19	−0.56	−0.59	−0.69
3	.....	1052	.....do	+0.10	−0.87	−1.43	−1.43	−1.26	−2.00	−2.50	−1.33	+0.01	−2.10	−1.86	−2.10
4	.....	1051	.....do	+0.34	+0.69	+1.43	+2.71	+2.40	+2.27	+0.88	+1.03	+0.91	+1.06	+0.84	+0.87
5	.....	551	Wm. Bond & Son	+3.43	+1.44	−0.07	−0.21	+0.27	+0.30	+0.52	+2.03	+4.10	+0.80	+0.91	+0.24

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Relative number.	Repaired by—	Chronometer number.	Maker.	Apr. 10 to Apr. 17	Apr. 17 to Apr. 24	Apr. 24 to May 1	May 1 to May 8	May 8 to May 15	May 15 to May 22	May 22 to May 29	May 29 to June 5	June 5 to June 12	Temperature of compensation.	Temperature constant.	Trial number.
Time				Apr. 10 to Apr. 17	Apr. 17 to Apr. 24	Apr. 24 to May 1	May 1 to May 8	May 8 to May 15	May 15 to May 22	May 22 to May 29	May 29 to June 5	June 5 to June 12			
Temperature, Fahrenheit.....degrees..				70.0	78.1	75.9	71.3	68.8	72.4	68.6	70.1	72.9			
Relative humidity.....per cent..				50	55	50	51	57	61	61	67	74			
1	.....	2941	John Bliss & Co	−4.49	−4.34	−4.59	−4.76	−4.84	−4.81	−4.91	−4.90	−4.89	69.3	+0.00270	10
2	Bond	49238	Dent.....	+1.06	+0.74	+1.13	+1.10	+1.49	+1.69	+1.67	+1.70	+1.50	67.9	+0.00062	10
3	.....	554	Wm. Bond & Son	−2.59	−2.69	−2.69	−2.83	−2.94	−2.97	−2.94	−2.97	−3.06	71.1	+0.00327	15
4	Negus	1281	T. S. & J. D. Negus	+1.81	+1.89	+1.91	+1.86	+1.77	+1.71	+1.77	+1.63	+1.49	73.1	+0.00234	16
5	Bond	548	Wm. Bond & Son	+0.23	+0.90	+0.76	+0.43	+0.30	+0.69	+0.51	+0.50	+0.71	66.9	+0.00236	16
6	.....	558	.....do	−2.80	−2.50	−2.61	−3.06	−3.09	−2.70	−2.70	−2.69	−2.43	61.4	+0.00288	19
7	.....	2934	John Bliss & Co	−1.30	−1.04	−1.26	−1.29	−1.49	−1.43	−1.61	−1.74	−1.70	67.6	+0.00257	19
8	Negus	1850	T. S. & J. D. Negus	−0.67	−0.74	−0.94	−0.69	−0.90	−1.19	−1.16	−1.11	−1.10	72.2	+0.00310	19
9	Negus	1710	Clerk	−0.10	+0.23	−0.16	−0.37	−0.01	+0.04	+0.23	+0.03	−0.03	67.7	+0.00257	20
10	.....	556	Wm. Bond & Son.....	−1.84	−2.03	−2.00	−1.97	−1.74	−2.03	−2.11	−2.26	−2.36	75.1	+0.00274	20
11	Negus	1074	T. S. & J. D. Negus.....	+0.09	+0.19	+0.11	+0.03	−0.09	−0.17	−0.27	−0.40	−0.34	69.9	+0.00411	20
12	Negus	1265	.....do	−1.89	−1.81	−1.87	−2.11	−2.26	−2.26	−2.26	−2.37	−2.41	69.4	+0.00399	20
13	.....	518	Wm. Bond & Son.....	−0.91	−0.57	−0.77	−0.89	−0.70	−0.90	−0.80	−0.71	−0.46	70.0	+0.00398	22
14	Bond	221	.....do	+1.49	+0.57	+0.16	+0.67	+1.64	+1.53	+1.66	+1.24	+0.94	67.4	+0.00107	22
15	Negus	1291	T. S. & J. D. Negus.....	+1.36	+1.56	+1.51	+1.20	+1.13	+1.19	+1.09	+1.07	+1.14	64.8	+0.00350	22
16	Bond	218	Wm. Bond & Son.....	−1.61	−1.47	−1.40	−1.97	−1.70	−1.79	−1.59	−1.64	−1.63	67.8	+0.00250	24
17	Bond	293	.....do	−0.27	−0.59	−0.46	−0.33	−0.19	−0.61	−0.47	−0.76	−1.00	74.1	+0.00300	28
18	Negus	1655	T. S. & J. D. Negus.....	+2.81	+2.81	+2.93	+2.80	+2.70	+2.86	+2.81	+2.77	+2.77	42.1	+0.00069	31
19	.....	2937	John Bliss & Co.....	−5.37	−5.07	−5.06	−5.89	−5.81	−5.93	−5.59	−5.74	−5.79	108.3	−0.00022	33
20	.....	2949	.....do	−5.21	−5.10	−5.37	−5.43	−5.09	−5.33	−5.76	−5.66	−5.56	68.2	+0.00285	33
21	.....	557	Wm. Bond & Son.....	−1.81	−1.89	−2.04	−1.73	−1.90	−1.64	−1.99	−2.43	−3.14	82.7	−0.00176	34
22	.....	48831	Dent.....	−2.77	−2.21	−2.44	−2.47	−2.51	−2.31	−2.40	−2.30	−2.21	77.7	−0.00154	38
23	Negus	725	T. S. & J. D. Negus.....	+1.91	+1.33	+1.61	+1.57	+1.70	+1.00	+1.01	+0.93	+0.73	76.9	+0.00278	46
24	Heinrich .	1016	H. H. Heinrich.....	+2.51	+1.97	+1.23	+1.71	+2.03	+0.91	+0.63	+0.71	+1.19	80.4	+0.00123	50
25	Bliss.....	2829	John Bliss & Co.....	+1.57	+1.04	+0.41	+0.17	+0.49	+1.14	+1.20	+0.93	+1.39	81.8	+0.00269	53
26	Bond	493	Wm. Bond & Son.....	−0.53	−0.36	−0.44	−0.60	−0.74	−0.60	−0.77	−0.79	−0.71	107.6	−0.00074	56
27	Bond	2851	Frodsham	−0.64	−0.60	−0.97	−1.00	−1.03	−0.96	−0.94	−0.83	−0.70	62.6	+0.00480	53
28	Bliss.....	49461	Dent.....	+1.94	+2.03	+2.15	+1.70	+1.77	+1.19	+1.44	+1.53	+1.09	77.4	+0.00311	60
29	.....	553	Wm. Bond & Son.....	−0.07	+0.11	−0.11	−0.50	−0.41	−0.21	−0.06	−0.61	−0.74	70.9	+0.00279	74
30	Bliss.....	2860	John Bliss & Co.....	−1.27	−1.10	−1.04	−1.16	−1.44	−1.50	−1.44	−1.64	−1.79	76.2	+0.00565	82
31	Bond	4667	Johannsen	−3.09	−3.15	−2.97	−2.77	−2.61	−3.47	−2.97	−3.86	−4.61	91.1	−0.00027	88
32	Bond	272	Wm. Bond & Son	−0.34	+0.10	+0.31	−0.66	−0.66	−0.29	−0.26	−0.16	+0.11	91.4	−0.00140	99
33	.....	47667	Dent.....	−0.41	+0.11	+0.20	−0.17	+1.27	+0.37	+0.01	+0.13	−0.17	−81.6	+0.00006	127
34	Bond	555	Nieberg	+1.80	+2.10	+1.77	+1.50	+1.94	+1.90	+1.41	+2.13	+1.90	61.5	+0.00509	482
1	.....	1037	H. H. Heinrich	−0.51	−0.50	−0.13	−0.29	−0.37	−0.17	−0.34	−0.36	−0.54	74.0	+0.00236	16
2	.....	1041	.....do	−0.59	.....	−0.39	−0.53	.....	−0.61	−0.66	−0.71	−0.60	66.7	+0.00378	25
3	.....	1052	.....do	−2.11	−1.96	−2.74	−2.61	−2.59	−2.39	−2.40	−2.41	−2.93	74.2	+0.00246	26
4	.....	1051	.....do	+0.96	+1.00	+1.63	+1.31	+0.49	+1.43	+0.80	+1.03	+1.19	58.0	+0.00226	27

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5	.....	551	Wm. Bond & Son	−0.23	−0.69	−0.93	−0.16	−0.34	−0.50	−0.40	−0.44	−0.73	79.6	+0.00298	30
6	.....	544	....do	+0.90	+1.54	+1.20	+0.67	+0.41	+0.83	+0.49	+0.49	+0.54	53.0	+0.00124	32
7	.....	1045	H. H. Heinrich	+1.87	+1.99	+1.76	+1.67	+1.34	+1.43	+1.20	+1.47	+1.89	58.5	+0.00212	35
8	.....	534	Wm. Bond & Son	+0.70	+0.59	+0.54	−0.11	+0.03	+0.17	+0.63	+0.31	+0.16	65.2	+0.00194	36
9	.....	1048	H. H. Heinrich	+0.24	+0.64	−0.19	−0.20	−0.57	−0.19	+0.09	+0.04	−0.04	64.8	+0.00350	50
10	.....	1049	....do	+0.41	+1.03	+1.21	+0.80	+0.41	+0.93	+0.84	+0.67	+1.69	68.7	+0.00426	53
11	.....	559	Wm. Bond & Son	−0.43	−0.99	−0.84	−0.71	−0.61	−1.10	−1.03	−0.87	−1.00	75.5	+0.00424	56
12	.....	1047	H. H. Heinrich	−1.91	−2.03	−2.21	−2.06	−1.87	−1.84	−1.87	−2.01	−2.03	70.4	+0.00533	58
13	.....	1044	....do	−2.20	−2.84	−2.53	−2.19	−2.51	−2.79	−2.50	−2.59	−2.71	76.5	+0.00302	59
14	.....	1046	....do	−4.24	−3.89	−3.47	−3.47	−3.70	−3.34	−3.49	−3.54	−3.00	71.6	+0.00585	81
15	.....	1050	....do	−0.49	−0.81	−3.29	−1.94	−1.33	−1.11	−0.90	−0.90	−1.29	68.0	−0.00219	236

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WATCHES.

The following table shows the number of stop and comparing watches:

	Issued.	Received.	Repaired.	On hand.	Held for repairs.
Comparing	24	17	5	28	15
Stop	27	11	4	8	6

During the year two torpedo-boat watches were issued; two remain on hand; one is ready for issue, and one is held for repairs.

THERMOMETERS.

During the year 26 maximum and minimum thermometers have been issued to ships and 81 are now ready for issue. Seventy-two have been purchased and four have been returned from ships.

THE TIME SERVICE.

During the year 156 observations for time were made. The three standard clocks and the two clocks for transmitting noon signals have performed fairly well. Noon signals were sent out every day in the year except Sundays. The average error for the year of noon signals (seventy-fifth meridian time) was 0.11 seconds.

Very respectfully,

B. W. HODGES,
Lieutenant-Commander, U. S. N., Head of Department.

REPORT OF THE DIRECTOR OF THE NAUTICAL ALMANAC.

NAUTICAL ALMANAC OFFICE,
UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., August 13, 1900.

SIR: I have the honor to submit the following report respecting the operations of the Nautical Almanac Office for the fiscal year ending June 30, 1900:

PRINTING.

The books published during the year were received from the Government Printing Office on the following-named dates: American Nautical Almanac for 1900, second edition, July 5, 1899; Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, volume 7, part 4, Tables of Neptune, July 17, 1899; American Ephemeris and Nautical Almanac for 1902, first edition, August 8, 1899; The Pacific Coaster's Nautical Almanac for 1900, first edition, September 8, 1899; Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, volume 7, part 3, Tables of Uranus, September 28, 1899; the American Ephemeris and Nautical Almanac for 1900, second edition, December 18, 1899; the American Nautical Almanac for 1901, second edition, January 5, 1900; the American Nautical Almanac for 1903, first edition, March 13, 1900; the American Ephemeris and Nautical Almanac for 1903, first edi-

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tion, April 21, 1900; the American Nautical Almanac for 1900, third edition, May 1, 1900; Supplement to the American Ephemeris and Nautical Almanac for 1900, entitled "Total Eclipse of the Sun, May 28, 1900," May 13, 1900.

DISTRIBUTION OF PUBLICATIONS.

During the fiscal year ending June 30, 1900, the sale and distribution of publications were as follows:

Title.	Sold.	Distributed.	Bureau of Equipment.	Public service.	Total.
American Ephemeris	958	359	233	591	2,141
American Nautical Almanac	2,152	.....	61	491	2,704
Pacific Coaster's Almanac	1,400	.....	7	8	1,415
Astronomical Papers	102	387	3	27	519

The proceeds of the above sales amounted to $1,844.46, and in compliance with law, that money has been deposited to the credit of the Treasurer of the United States, on account of public printing and binding.

THE AMERICAN EPHEMERIS.

The law authorizing the publication of the American Ephemeris contemplates the issue of each volume three years in advance of its date, but, as mentioned in the report for the year 1899, the extra work incident to the preparation of a series of tables of the major planets of the solar system retarded the Ephemeris to such an extent that the first edition of the volume for 1901 was not received from the Government Printing Office until April 5, 1899. Every available computer was taken from other work and placed on the Ephemeris to bring it up to the point required by law. By this means the first edition of the Ephemeris of 1902 was received on August 9, 1899, and the volume for 1903 was issued in April, 1900. The work on 1904 is so far advanced that this office can give every assurance that 1904 will be issued by January 1, 1901, making this publication completed full three years in advance of its date. All of the Almanac and three-fourths of the Ephemeris of 1904 are already in type.

The Pacific Coaster's Almanac for 1901 is now in type, and will be published before the end of August, thus making a considerable advance in the date of this publication.

The changes made in the Ephemeris for 1903, as mentioned in the former report, are continued in the Ephemeris for 1904.

NEW TABLES OF THE PLANETS.

The Astronomical Papers prepared for the use of the American Ephemeris and Nautical Almanac, volume 7, part 3, Tables of Uranus, were issued September 28, 1899, and the Tables of Neptune, volume 7, part 4, were issued July 17, 1899.

NEW INVESTIGATIONS.

The formation of a catalogue of about 2,500 zodiacal stars, mentioned in the former report as having been begun, is now well advanced, and should be finished and issued by the end of the next fiscal year.

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The revision of the elements used in the American Ephemeris for the outer planets of the solar system has been continued. This work, as stated in the former report of this office, was confined to the satellites of Mars and to the fifth satellite of Jupiter. It has since been extended to the reduction of several hundred observations for the determination of new elements of the seven inner satellites of Saturn.

These computations are not progressing as rapidly as I would wish, nearly the whole force being confined to the work on the Ephemeris, coupled with the fact that this office has been shorthanded from death or resignations of assistants since February, 1900.

Very respectfully,

HENRY D. TODD,
Professor of Mathematics, U. S. N., Director Nautical Almanac.

The SUPERINTENDENT U. S. NAVAL OBSERVATORY,
Georgetown Heights, D. C.

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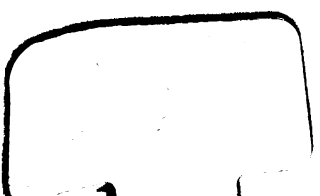

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